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AIR POLLUTION ASPECTS OF PESTICIDES

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Bethesda, Maryland

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AIR POLLUTION ASPECTS
OF
PESTICIDES

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FOREWORD

As the concern for air quality grows, so does the concern over the less ubiquitous but potentially harmful contaminants that are in our atmosphere. Thirty such pollutants have been identified, and available information has been summarized in a series of reports describing their sources, distribution, effects, and control technology for their abatement.

A total of 27 reports have been prepared covering the 30 pollutants. These reports were developed under contract for the National Air Pollution Control Administration (NAPCA) by Litton Systems, Inc. The complete listing is as follows:

Aeroallergens (pollens)
Aldehydes (includes acrolein and formaldehyde)
Ammonia
Arsenic and Its Compounds
Asbestos
Barium and Its Compounds
Beryllium and Its Compounds
Biological Aerosols (microorganisms)
Boron and Its Compounds
Cadmium and Its Compounds
Chlorine Gas
Chromium and Its Compounds (includes chromic acid)
Ethylene
Hydrochloric Acid
Hydrogen Sulfide
Iron and Its Compounds
Manganese and Its Compounds
Mercury and Its Compounds
Nickel and Its Compounds
Odorous Compounds
Organic Carcinogens
Pesticides
Phosphorus and Its Compounds
Radioactive Substances
Selenium and Its Compounds
Vanadium and Its Compounds
Zinc and Its Compounds

These reports represent current state-of-the-art literature reviews supplemented by discussions with selected knowledgeable individuals both within and outside the Federal Government. They do not however presume to be a synthesis of available information but rather a summary without an attempt to interpret or reconcile conflicting data. The reports are necessarily limited in their discussion of health effects for some pollutants to descriptions of occupational health exposures and animal laboratory studies since only a few epidemiologic studies were available.

Initially these reports were generally intended as internal documents within NAPCA to provide a basis for sound decision-making on program guidance for future research activities and to allow ranking of future activities relating to the development of criteria and control technology documents. However, it is apparent that these reports may also be of significant value to many others in air pollution control, such as State or local air pollution control officials, as a library of information on which to base informed decisions on pollutants to be controlled in their geographic areas. Additionally, these reports may stimulate scientific investigators to pursue research in needed areas. They also provide for the interested citizen readily available information about a given pollutant. Therefore, they are being given wide distribution with the assumption that they will be used with full knowledge of their value and limitations.

This series of reports was compiled and prepared by the Litton personnel listed below:

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ABSTRACT

The air pollution aspects of those synthetic organic pesticides that currently are most widely used and are potential health hazards to humans, domestic and commercial animals, fish, and wildlife have been discussed. Of all the pesticides, the chlorinated hydrocarbons and organophosphorous insecticides are of the greatest concern as health hazards because of inherent toxicity or persistence of residues. The acute toxicity of the organophosphates, on the average, is somewhat greater than that of the chlorinated hydrocarbons, but the latter present a greater residue problem because of their greater persistence. This persistence characteristic has resulted in residue levels of DDT, in particular, in human and animal fat tissue in all parts of the world, and adverse health effects in some wildlife. However, there is no medical evidence at the present time that the storage levels found in humans can produce chronic adverse health effects.

Toxicity studies are in progress using experimental animals, and the results are used as guidelines for establishing tolerances for pesticide residues. Plants can be accidentally damaged by herbicides, and some insecticides can impart an undesirable flavor to food crops.

There have been no reports of damage to inanimate materials from pesticides as such, but some of the solvents

used in spraying applications could have a damaging effect on paint and other surfaces.

Preliminary estimates for 1967 place production of pesticides in the United States at slightly in excess of 1 billion pounds and the manufacturers' value at approximately 900 million dollars. Agriculture is the leading user of pesticides in this country. The primary source of pesticides in the air is from the application process, and a certain amount of drift is unavoidable even under ideal conditions. Pesticides can volatilize into the air from soil, water, and treated surfaces, and pesticides containing dust from the soil can enter the ambient air and be transported for considerable distances before falling back to the earth. Pesticides have been detected in the ambient air of local areas where used, and have also been found in urban and rural areas; as expected the rural areas usually contain the highest concentrations.

The abatement and control measures for air contamination employed by the chemical industry in general are used in pesticide production facilities. The control of pesticide drift during application is being approached by improving application equipment and methods, improving pesticide formulation, and by distributing micrometeorological data more extensively.

Pesticides have contributed to the eradication or reduction of a number of human diseases both in the United States and in other parts of the world. Our present agricultural efficiency is maintained only through the use of pesticides. It is estimated that nationally about five dollars are saved for every dollar invested in chemical pesticide usage. The economic losses due to pesticide air pollution have not been estimated.

Efforts to measure pesticides in the ambient air have been handicapped in the past by the lack of methods of sufficient sensitivity for these materials. However, in recent years significant advances have occurred in instrumentation for detection and analysis of low concentrations.

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1. INTRODUCTION

Pesticides, or economic poisons, include a spectrum of chemicals used to control or destroy pests that cause economic losses or adverse human health effects. These chemicals can be grouped as insecticides, herbicides (weed and brush killers, defoliants, and desiccants), fungicides, rodenticides, ascaricides, nematocides, molluscacides, algaecides, repellents, attractants, and plant growth regulators. There are presently approximately 45,000 registered pesticide formulations using some 900 chemicals. These are employed in agriculture, forestry, food storage, urban sanitation, and the home.

The pesticides are meant to be toxic to certain forms of life--the pests which are the targets of control. However, only a small portion of the total quantity of the pesticide used affects the target pest; the remainder enters the environment as a contaminant and may affect other forms of life directly or indirectly. Depending upon the target of control, the application of a pesticide may contaminate soil, water, air, plants, animal life, and humans. Pesticides in the air may settle in other parts of the environment close to the site of application or be carried some distance by air currents. Pesticides in the soil may remain on the surface, be washed off by rain, be blown into the air, or be absorbed by plants. In water, pesticides may be absorbed by aquatic forms of life. Pesticides on plant surfaces may wash off into the soil or water or be ingested as a residue by animals or humans when these plants are utilized as a food. Pesticides applied directly to animals or humans may be washed off into the environment or be absorbed. Thus, a complex cycle exists for the distribution and fate of a pesticide in the environment; the extent of distribution is dependent upon the ease with which the specific pesticide is degraded and the volume and method of its use.

Pesticide usage and environmental distribution is investigated by the Federal Committee on Pest Control, which represents the Departments of Defense; Interior; Agriculture; and Health, Education, and Welfare. The purpose of the Committee is to assure necessary control of pests without hazard to the environment and its inhabitants through coordination and review of the varied aspects of control programs, research, and environmental monitoring for pesticides.

Because of the magnitude and complexity of the subject of pesticides, it is not the intent of this report to review all aspects of the topic. The content of this report is limited primarily to those aspects of the subject that are concerned with air contamination and to the synthetic organic pesticides that are currently the most used and that are potential health hazards to humans, domestic and commercial animals, fish, and wildlife because of inherent toxicity or persistence. Other pesticides have been included in some of the production and use tables for comparative purposes. The arsenicals and mercurials are discussed in companion reports of this series. The list of pesticides tabulated for the Subcommittee on Pesticide Monitoring of the Federal Committee on Pest Control[79] has been used as a guideline.

A glossary of common names and abbreviations of pesticides is given in Appendix B. The reader may also find it useful to examine Tables 9, 10, 22, 23, and 24 in Appendix A, which group some of the more common pesticides according to type and use.

2. EFFECTS

2.1 Effects on Humans

Pesticides are intended to be especially toxic only for certain forms of life: insecticides for insects, herbicides for plants, fungicides for fungi, etc. In general, however, these specific uses have proved to be more quantitative than qualitative. At a sufficiently high dosage, these materials can cause adverse effects in humans as well. Pesticides can enter the body by ingestion, absorption through the intact skin, or by inhalation; and if the dosage is sufficiently high for each means of exposure, the effects will be the same.

Cases of poisoning, both accidental and occupational, have been reported for practically every known insecticide in all countries where they are used.[24] In general, chemicals given at equivalent dosages are absorbed more rapidly and more completely through the respiratory tract than through the skin. In cases of accidental occupational poisonings, it has usually been impossible to determine if the exposure was predominantly respiratory or dermal.[27] Therefore, data from dermal as well as ingestion studies have been included in the present report to describe the effects on humans so that the relative importance of respiratory exposure may be better evaluated.

2.1.1 Insecticide Effects and Toxicities

The chlorinated hydrocarbons and the organophosphates are the two most important groups of synthetic organic insecticides because of their wide use and toxicity to humans. On the average, the acute toxicity of the organophosphate compounds is somewhat greater than that of the chlorinated hydrocarbon compounds. However, the chlorinated hydrocarbons, because of their greater stability, may present a greater residue problem than do the organophosphates.

As a group, the chlorinated hydrocarbons are more chemically stable in the environment than are the organophosphates. They are not easily biodegradable and persist for long periods of time. When absorbed into the body, some of the chlorinated hydrocarbons are not metabolized rapidly but are stored in the fat tissue. DDT, BHC, and dieldrin have been found in the body fat of people in the general population whose only significant exposure to these insecticides has been through foods.[41] The consequences of such storage are presently under extensive investigation by many researchers. The organophosphates do not present a great residue problem in the body since they are metabolized much more rapidly than the chlorinated hydrocarbons.

2.1.1.1 Chlorinated Hydrocarbons

The chlorinated hydrocarbons, as a general group of insecticides, can be absorbed into the body through the respiratory tract, digestive tract, or the skin or mucous membranes. The symptoms of poisoning, regardless of the specific chlorinated hydrocarbon involved or the method of entry, are similar but may vary in severity. Mild cases are characterized by headache, dizziness, gastrointestinal disturbances, numbness and weakness of the extremities, apprehension, and hyperirritability. In more severe cases, fine muscular tremors appear, spreading from the head to the extremities. Eventually, there are jerking movements involving whole muscle groups, finally leading to convulsions. Death from cardiac or respiratory arrest may occur.[85] There is evidence that the severity of symptoms is related to the concentration of the insecticide in the nervous system, primarily the brain.[22]

The chlorinated hydrocarbons for the purpose of this report can be subdivided into four major groups: the DDT group, aldrin-toxaphene group, benzene hexachloride group, and other chlorinated hydrocarbons.

2.1.1.1.1 DDT Group

The three major insecticides of this group are (1) DDT (including its isomers and dehydrochlorination products), (2) TDE (including its isomers and dehydrochlorination products), and (3) methoxychlor.

(1) DDT, the first of the synthetic organic insecticides to have widespread usage, currently ranks as the most used insecticide. Its primary importance is in Anopheles mosquito control, control of crop insects, and as a pediculicide applied topically as a 5 to 10 percent lotion, emulsion, ointment, or powder. Acute poisoning may result in tremors of the head and neck muscles, tonic and clonic convulsions, cardiac or respiratory failure, and death. The estimated oral fatal dose is 500 mg/kg body weight of the solid material, with death occurring in 2 to 24 hours. Effects of chronic poisoning may include hepatic damage, central nervous system degradation, agranulocytosis, dermatitis, weakness, convulsions, coma, and death.[61]

(2) TDE (DDD), which is less toxic to humans than DDT, can be slightly irritating to the skin. Acute poisoning produces lethargy but no convulsions. The estimated fatal oral dose is 5/g/kg body weight. Chronic poisoning leads to atrophy of the adrenal cortex and liver damage.[61]

(3) Methoxychlor, used to control insect pests of crops and livestock, may be slightly irritating to the skin, but not appreciably absorbed through it. The estimated fatal oral doxe is 7.5 g/kg body weight. Continued ingestion over long periods of time may cause kidney damage.[61]

2.1.1.1.2 Aldrin-Toxaphene Group

This group of chlorinated hydrocarbon insecticides includes the following:

(1) Aldrin, which may produce severe poisoning symptoms after ingestion of percutaneous absorption of 1 to 3 g, especially if a liver disease already exists. Acute poisoning may cause renal damage, tremors, ataxia, and convulsions followed by central nervous system depression, respiratory failure, and death. Prolonged exposure may cause hepatic damage.[61]

(2) Chlordane, which is moderately irritating to the skin. Poisoning can occur by ingestion, inhalation, or percutaneous absorption. Acute poisoning may be characterized by irritability, convulsions, and deep depression. Continued ingestion may cause degenerative changes in the liver.[61]

(3) Dieldrin, which is readily absorbed through the skin and has toxic effects similar to DDT.[61]

(4) Endrin, which exhibits toxic effects similar to aldrin and dieldrin.[61]

(5) Heptachlor. Poisoning may occur by ingestion, inhalation, or skin contamination. Acute poisoning may be characterized by tremors, ataxia, convulsions, renal damage, respiratory failure, and death, the latter resulting from ingestion of or skin contamination with 1 to 3 g. There are some indications that chronic poisoning with small quantities may cause hepatic damage.[61]

(6) Strobane, which may be mildly irritating to the skin. Large doses may cause central nervous system stimulation with tremors and convulsions.[61]

(7) Toxaphene, which can cause mild irritation of and be absorbed through the skin. Central nervous system stimulation with tremors, convulsions, and death may result.

2.1.1.1.3 Benzene Hexachloride Group

(1) BHC (benzene hexachloride) is a local irritant which may be absorbed through the skin. Acute toxic effects may include excitation, hyperirritability, loss of equilibrium, convulsions, and later depression.[77]

(2) Lindane (gamma isomer of BHC) as a 1 percent lotion or cream is used topically as a scabicide and pediculicide. Poisoning may occur by ingestion, inhalation, or percutaneous absorption. Acute poisoning may be indicated by dizziness, headache, nausea, vomiting, diarrhea, tremors, weakness, convulsions, dyspnea, cyanosis, and circulatory collapse. The estimated oral fatal dose is 150 mg/kg body weight. Topical use may cause local sensitivity reactions, and vapors may irritate the eyes, nose, and throat. Some evidence suggests that chronic toxicity may cause hepatic damage.[61]

2.1.1.1.4 Other Chlorinated Hydrocarbons

(1) Mirex is suspected to be highly toxic although there are no specific data on its toxicity.[61]

(2) p-Dichlorobenzene is an irritant which may cause headache, nausea, vomiting, weakness, cataract, and anemia after a prolonged exposure to its vapors.[61]

2.1.1.2 Organophosphates

The first symptoms of organophosphate poisoning are usually loss of appetite, nausea, and headache. These are followed by vomiting, abdominal cramps, excessive sweating and salivation, and usually pupillary constriction. A large dose of an organophosphate will also cause diarrhea, loss of sphincter control, excessive bronchial secretion, and a feeling of tightness in the chest that may be accompanied by pulmonary edema. In severe cases, convulsions and coma occur, and death may follow respiratory failure. In most cases the body temperature does not rise and there are no signs of meningeal irritation. The symptoms of organophosphate poisoning are rapid in onset, and death can occur within 5 minutes to several hours following exposure. If symptoms begin more than 12 hours after the last known exposure to an insecticide, the illness probably is not due to organophosphate poisoning. The first 6 hours of the poisoning are critical; if the individual survives this period, he will usually recover. The organophosphates are toxic because they inhibit the enzyme acetylcholinesterase, resulting in an accumulation of acetylcholine which causes symptoms of excessive stimulation of the parasympathetic nervous system.[40,111]

The organophosphates used as insecticides are in themselves generally poor acetylcholinesterase inhibitors. The mechanism of their action is dependent upon their being converted metabolically to other products that are good inhibitors. This conversion occurs relatively rapidly in invertebrates. This fact, combined with the poor ability of invertebrates to detoxify these materials, makes invertebrates highly susceptible to the organophosphates. Mammals also oxidize these insecticides to acetylcholinesterase inhibitors but at a slower rate than insects. Also, mammalian detoxification of these compounds occurs at a higher rate, resulting in a lower level of mammalian susceptibility to the toxicity of organophosphates.[64,96].

Some of the organic phosphorous insecticides are described below.

(1) Parathion is highly toxic and special precautions should be taken to prevent inhalation and skin contamination. Acute symptoms may include anorexia, nausea, vomiting, diarrhea, excessive salivation, pupillary constriction, bronchoconstriction, muscle twitching, convulsions, coma, and respiratory failure.[61]

(2) Methyl parathion has a toxicity similar to parathion.[61]

(3) Malathion induces toxicity symptoms similar to parathion, but is considered to be less toxic.[61]

(4) Disulfoton is permitted in the feed and drinking water of animals and is used as a pesticide on food-producing animals. Its human toxicity is not known.[77]

(5) Guthion exhibits toxicity symptoms similar to parathion.[61]

(6) Demeton is readily absorbed through the skin. Its toxicity symptoms are similar to parathion.[61]

2.1.2 Herbicide Effects and Toxicities

(1) 2,4-D can cause irritation of the eyes and gastrointestinal disturbances.[61]

(2) 2,4,5-T has a toxicity similar to 2,4-D.[61]

(3) Silvex has caused liver and kidney injury and muscular disturbances in experimental animals.[61]

(4) Atrazine has shown low toxicity in limited animal experiments.[77]

(5) Simazin has been reported as causing irritation of mucous membranes.[77]

(6) Amitrole has shown a low toxicity in limited animal experiments.[77]

2.1.3 Fungicide Effects and Toxicities

(1) Maneb has caused allergic dermatitis in humans.[77]

(2) Ferbam may cause irritation of skin and mucous membranes and renal damage.[61]

(3) Zineb is irritating to the skin and mucous membranes. Animal experiments suggest a low toxicity.[77]

2.1.4 Specific Effects and Case Histories

2.1.4.1 Experimental Studies

Studies have been performed in which human volunteers have ingested quantities of pesticides. Hayes *et al.*[43] in 1956 observed one group of 51 men divided into three approximately equal groups. The first group received no DDT except that which occurred in their normal diet. A second group was fed 3,500 μg/man/day of DDT, and a third group was fed 35,000 μg/man/day of DDT. At no time during daily exposure for up to 18 months did any of the men show any acute symptoms indicative of DDT poisoning. The fat storage levels of DDT reached an equilibrium in about one year. The average fat storage levels of DDT in the men who received 35,000 μg/day were 340 ppm and 234 ppm for those ingesting 3,500 μg/day.

Hunter and Robinson[47] reported on a study in which nine adult males deliberately ingested HEOD (the major compound (~85%) in dieldrin) for 18 months without any observable effects on their health. These men were divided into three groups of three men each; the first group received 10 μg of HEOD per day, the second 50 μg per day, and the third 211 μg per day. During the experimental period, the initial rates of increase in body storage of HEOD progressively declined, and the eventual storage level was characteristic of each individual and his particular daily intake. In general, the levels of the first group did not differ from those of four male controls; the second group had a fourfold increase in storage levels; and the third group had an increase of tenfold. The concentration of HEOD in the fat tissue of the men in all groups ranged from 0.80 to 4.94 ppm in samples taken 749 days after the beginning of the study. It appeared to Hunter and Robinson that the body storage levels of the men receiving 211 μg of HEOD per day if continued through life, would become 12 times those of the general population, although exposures were approximately 11 times greater.

Gamelin _et al_.[32] conducted a survey in the Phoenix, Ariz. area on the effect of exposure to parathion on the general population and on asthmatics. A total of 122 volunteer subjects were placed into five approximately equal groups in the following manner:

Group 1: Nonasthmatic, no exposure to organophosphorous insecticides.

Group 2: Nonasthmatic, environmental exposure to organophosphorous insecticides.

Group 3: Asthmatic, no exposure to organophosphorous insecticides.

Group 4: Asthmatic, environmental exposure to organophosphorous insecticides.

Group 5: Nonasthmatic, occupational exposure to insecticides, including organophosphorous compounds.

The persons in Groups 2 and 4, with environmental exposure, lived less than 500 yards from cotton fields being treated by aerial application of insecticides, primarily parathion. Unexposed persons in Groups 1 and 3 lived and worked in Phoenix and had no special contact with insecticides. The occupationally exposed Group 5 was composed of formulators, crop dusters, loaders, and mechanics. The study was performed from June to December; July to September was the period of heaviest insecticide application to the cotton crop, June and October smaller, and May, November, and December almost negligible. Throughout the study, although the exposed groups reported the odor and mucous membrane irritation due to the insecticides, no individual had symptoms resembling those of organophosphorous poisoning. In addition, there was no significant incidence of cholinesterase depression in Groups 2 and 4 when compared with their controls, and p-nitrophenol excretion measurements indicated that the actual insecticide exposure of all persons other than those in the occupational group was small. The incidence of asthma in the exposed and unexposed groups was similar and roughly followed the same seasonal occurrence indicative of common causative agents such as pollens, molds, and other aeroallergens. Although no quantitating of the severity of the asthmatic attacks was made, the investigators concluded that if insecticides do affect preexisting bronchial asthma, the effect is a relatively minor one.

2.1.4.2 Occupational Exposures

Hartwell and Hayes[39] investigated two formulating plants in which poisonings among the workers by organic phosphorous pesticides had been reported. The poisonings and cholinesterase activity depression were due to inadequate respiratory protection for the workers. In one plant only a canister-type respirator was in use, and in the other the supply of compressed air was being contaminated. Proper modification of the air supplies resulted in return of cholinesterase activity to normal, and no additional poisonings due to parathion and phosdrin occurred. In the same report, Hartwell and Hayes mentioned illnesses in two crop-dusting pilots who had continued to dust crops with no respiratory protection after their supply of compressed air had been exhausted. When they returned to work and used the proper respiratory protection, their cholinesterase levels returned to normal, although the environmental exposure level remained the same.

Laws *et al.*[52] examined 35 men with 11 to 19 years of occupational exposure to DDT in a production plant. Findings from medical histories, physical examinations, routine clinical laboratory tests, and chest X-rays did not show any ill effects that could be attributed to the DDT. It was estimated that the average daily intake of DDT by the 20 men with the highest occupational exposure was 17,500 to 18,000 µg/man/day as compared to an average of 40 µg/man/day for the general population. The fat storage levels of the men were 38 to 647 ppm.

Culver _et al_.[21] observed a worker handling malathion while loading equipment for two weeks during which he was being exposed to an air concentration of about 3,300 µg/m^3 of parathion. It was estimated that he had inhaled about 11,000 to 21,000 µg of malathion during that time but exhibited no ill effects.

Durham and Wolfe[28] studied the occupational exposure received by workers while applying pesticides. Some of their calculated exposure rates are presented in Table 1, Appendix A. The respiratory exposure represented only a small fraction of the dermal exposure.

Davignon _et al_.[24] concluded from a study of a group of apple growers that insecticides used by such an occupationally exposed group may have some chronic effects in humans. They found a greater incidence of leukopenia and neurologic symptoms among this group than in the general population. However, because of the relatively short period of total exposure and the limited number of test subjects, they recommended that this occupational group be reexamined at

5-year intervals until a sufficient number of apple growers had been exposed for a long enough period of time to make definite conclusions.

Jegier[49] in studying the occupational hazard for operators of spray equipment both indoors and outdoors and during aerial application found no ill effects in the workers examined.

Epileptic-type symptoms have been reported after exposure to aldrin.[50] A 23-year-old worker, who mixed aldrin with fuller's earth in a formulating plant, developed epileptiform convulsions after 1 week of heavy exposure. Nine other exposed workers were examined, and two were found to have symptoms suggestive of aldrin poisoning: involuntary jerking of the hands and forearms, irritability, headaches, rash, and nausea. At a later date, one of the latter two and one other suffered convulsions and unconsciousness. In all cases, abnormally high levels of blood and fat dieldrin* concentrations were associated with abnormal electroencephalogram activity. One subject had a fat storage level of 60 ppm, which is approximately 300 times higher than that found in the general population. The acuteness of the symptoms was caused by the high exposure level and the fact that aldrin can be absorbed into the body through the intact skin and by inhalation, as well as by ingestion.

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*HEOD, the metabolized form of aldrin.

Barnes[10] described the occurrence of convulsions caused by chlordane poisoning in an individual. The subject, a nurseryman, had handled daily soil and plants treated with chlordane for a period of 1 year before the first seizure and hospitalization. His illness was not recognized as chlordane poisoning at that time and he returned to work. A year later, after still handling chlordane-treated soil and plants, he required rehospitalization because of two additional convulsive epileptic-type seizures.

A large number of parathion poisonings among peach pickers was reported in California.[65] The symptoms primarily were nausea, vomiting, occipital headache, profound weakness, and extreme malaise. It was found that these workers were being exposed to not more than 4,000 μg/day of parathion, a quantity which is approximately one-half that required to precipitate an acute reaction. Apparently at these low levels of exposure, their cholinesterase levels were being chronically depleted, and at some critical point recurrent mild symptoms were noted. The unusual lengthy persistence of the parathion residues led Milby _et al_.[65] to believe that the cause of the poisonings was due to a paraoxon derived from parathion, paraoxon having a cutaneous toxicity of about tenfold that of parathion.

West and Milby[104] summarized the occurrences of occupational diseases attributed to pesticides and other agricultural chemicals in California (see Tables 2 and 3, Appendix A), where approximately 20 percent of the nation's pesticides are used and 40 percent of the nation's vegetables are grown.

2.1.4.3 Nonoccupational Exposures

Quinby and Doornink[73] reported nonoccupational poisonings from 1 percent tetraethyl pyrophosphate (TEPP) dust in Toppenish, Wash., in August 1963. The poisonings occurred following the aerial dusting of hop vines in which the dust cloud drifted at least 700 feet beyond the vineyards over adjacent pastures, fields of corn, and other crops, and homes. The dust hung in the air as a cloud about 3 feet above the ground and did not lift or move for almost 2 hours. The occurrence of dust clouds in the area was not unusual, but the 2-hour period of thermal inversion of air was rare. Of a total of 11 people in a nearby farmhouse, five who had spent 30 minutes or more outdoors during the 2-hour period showed symptoms of shortness of breath. The six who had remained indoors did not complain of any symptoms. Cattle near the house showed severe symptoms and two heifers died. In addition, 10 other persons in the vicinity of the dust cloud complained of shortness of breath. Of the 15 persons who had complained of symptoms, all but 3 recovered before arriving at the hospital, and these 3 recovered within a few hours without any treatment. The flagman who worked directly under the application of the TEPP dust and wore no respirator did not complain of any symptoms.

Quinby and Clappison[72] reported a case of unusual persistence of parathion. A 2-year-old boy had eaten mud on which a parathion concentrate had accidentally leaked 6 months previously. The soil had been leached by water and snow for 6 months and still remained sufficiently toxic when ingested to cause an acute poisoning in the youngster.

West and Milby[104] reported four deaths in California due to the use of lindane in the home. Other incidents have also been reported.

2.1.4.4 Chlorinated Hydrocarbons in Body Fat

The concentration of DDT in the fat depots of individuals in the general population has been monitored for many years. Sufficient evidence exists that the general world population now carries a body burden of DDT, and the level in any given individual is dependent on his history of exposure.[78] Quinby _et al_.[74] reported a mean storage level in the body fat of 12.6 ppm of DDT and DDE (a degradation product of DDT) for the population in the United States in 1961 to 1962. This value of 12.6 ppm was not significantly different from that observed for the population in 1954 to 1956.

The DDT storage level in the United States is slightly more than that in Canada or most of Europe.[70] The average storage level of BHC is less in this country (0.2 ppm) than in France (1.19 ppm), and the U.S. dieldrin storage level is 0.15 ppm as compared with 0.21 ppm in southern England. West[103] tabulated 32 reports that have appeared in the literature prior to 1965 on DDT, dieldrin, and BHC storage levels in human fat including the country, the year, and the investigators.

Regarding chronic effects and toxicity of stored dieldrin, Heath and Vandeker[45] concluded that symptoms should not appear later than 2 months after the last exposure unless fat depots are greatly decreased by illness or starvation, and there should not be any special sensitivity to a second dose after 6 months.

Campbell et al.[16] estimated the annual relative contribution of the various environmental sources to the human body burden of DDT and DDE. They concluded that food sources constitute the chief source of DDT intake, and that air only represents 0.06 percent of the total (Table 4, Appendix A).

2.1.4.5 Accidental Deaths

Hayes and Pirkle[42] have presented a review of the pesticides responsible for accidental deaths in the United States in 1956 and 1961. The number of deaths for these 2 years and the associated pesticides are shown in Table 5, Appendix A. There were 119 deaths in 1961 possibly related to pesticides, and 111 were ascribed to identifiable materials. Of the 111 cases, 57 (51 percent) were in children under 10 years of age; at least 64 (58 percent) were caused by compounds in use before the introduction of DDT; not more than 17 (15 percent) were occupational; and several cases were associated with alcoholic intoxication, mental deficiency, improper storage of the pesticide, or some other special circumstance. Insecticides caused 62 of the 111 deaths; herbicides, 15; rodenticides, 25; fungicides, 2; and 7 were unspecified. The distribution of deaths according to age and route of exposure and whether occupational is presented in Table 6, Appendix A. Five deaths of the total were attributed to respiratory exposure.

Accidental deaths from pesticides and other agricultural chemicals in California from 1951 to 1963 are listed in Table 7 in Appendix A.

2.2 Effects on Animals

2.2.1 Commercial and Domestic Animals

Pesticides are generally introduced into the environment of commercial and domestic animals by direct treatment of the animal for pest control and by pesticide residues in feed. Usually, such animal exposures are carefully controlled and no ill effects are noted. However, accidents have occurred, and Street[90] cites a personal communication from Radeleff in 1963 stating that pesticide accidents account for 0.5 to 1.0 percent of all domestic animal losses from disease. These acute poisoning accidents usually were due to carelessness or misuse of the pesticides and involved the more toxic organophosphates in addition to endrin and dieldrin. As in humans, chronic effects have been difficult to identify in domestic and wild mammals.[90] The chlorinated hydrocarbons generally can penetrate the skin if applied in an oil solution or emulsion, and dieldrin can be absorbed in the dry powder form. Except for methoxychlor, all are stored in the body fat at various levels.[18] Again as with humans, the significance of this storage on health is not completely understood.

The presence of DDT and other stored pesticide residues in the secreted milk of dairy animals has been of concern since it relates to humans and it also provides a method for study of these residues. In addition to DDT, small amounts of BHC, chlordane, and dieldrin are also in the secreted milk. Only insignificant amounts of Toxaphene are present, and practically no methoxychlor. After ingestion of as little as 7 to 8 ppm of DDT on hay (a normal residue following spraying), approximately 3 ppm will be secreted in cow's milk, and butter made from such milk will contain about 65 ppm.[108] Witt _et al_.[108] in their studies found that DDT present in cow's milk in Arizona fluctuated seasonally with a low of about 1.0 ppm in the milk fat in the late spring and early summer and a high of 3.0 to 3.5 ppm in the late fall and early winter. This fluctuation was correlated with ingestion of residue in the feed at the higher dosage levels but not at the lower levels. They also studied the relative importance of respiratory (intratracheal) exposure of the cows as compared with other means of exposure to DDT. Their results (Table 8, Appendix A) showed that intratracheal exposure resulted in slightly less total excretion of DDT and its metabolites in milk than either of the two alimentary modes of exposure.

Fowl, fish, and many lower forms of wildlife have been extremely susceptible to low dosages of DDT and related insecticides. DDT residues in the bodies of such animals have been reported in all parts of the world, including penguins in the Antarctic.[83] Birds are particularly affected by such residues because they interfer with calcium deposition in eggs. Thin-shelled eggs are laid thus causing a loss in reproduction. West[102] and Dustman[29] have reviewed many of these occurrences of the effects on wildlife.

Cattle have been poisoned by drifting dust of 1 percent TEPP. Three incidences occurring in Washington in August 1963 were observed and documented.[73] Each involved the drift of TEPP dust from a hop vineyard to adjacent areas, and a prolonged static condition of the air resulted in an extra high exposure of the animals. In one instance, 15 cattle showed symptons of staggering, gasping for air, drooling, and some degree of cyanosis; two young cows died within the second hour after onset of the symptoms. Two geese, a cat, and chickens in the same dust cloud were not harmed. In another incident, a heifer in an open barn began coughing and developed symptoms of respiratory stress within 30 minutes of initial exposure. It was given one-fourth grain of atropine and was normal by the next morning. In the third incident, 17 head of cattle became severely ill after exposure to TEPP dust, with symptoms of diarrhea, excessive urination, wobbly gait, and loss of appetite. All recovered without special treatment.

The phenoxyacetic acid herbicide derivatives (2,4-D and 2,4,5-T) are comparatively harmless to most animals. All of the alleged cases of herbicidal poisoning of livestock and wildlife have been diagnosed as due to things other than herbicides. Inhalation of these herbicide dusts and sprays is relatively harmless, and percutaneous absorption is negligible. Even when administered to cows in large doses by ingestion, 2,4-D has not been found in the secreted milk. In cattle, a daily dose rate of 3,000 μg/kg body weight of

2,4-D or 2,4,5-T can be tolerated for long periods. However, at higher dosages of 100,000 μg/kg, pathological changes occur if feeding is continued for over a week, and at repeated doses of 1 gm/kg, illness and death result. Horses, cattle, sheep, pigs, and chickens have foraged on pastures freshly sprayed with 2,4-D or 2,4,5-T at two to four times the normal application with no ill effects. Exposure of poultry to abnormally high residues of these herbicides led to reduced egg production but did not affect fertility or hatchability.[18]

The main hazard to livestock from fungicides is likely to arise from their use as seed-dressings for the protection of stored grain, potatoes, and other crops. However, the newer fungicides such as dodine, zineb, and maneb appear to present little toxic hazard.[18]

2.2.2 Experimental Animals

Extensive studies using experimental animals have been and are currently being performed to learn more about the biological effects of pesticides and their toxicity, mechanism of action, and metabolism.

Compared with the total number of such studies, relatively few have utilized air as the means of exposing animals to the pesticide. However, because of the distribution and potential recycling of pesticides in the total environment, the results of ingestion-exposure studies are significant. Therefore, the following discussion will be concerned with some of the important areas of study, regardless of the means of exposure, in which the findings are relevant to air pollution aspects.

The acute oral and dermal LD_{50} values of the most common insecticides are listed in Table 9, Appendix A. The listed values were assembled by the Pesticides Program, National Communicable Disease Center, Public Health Service, U.S. Department of Health, Education, and Welfare.[92]

Data on long-term feeding of low dosages of pesticides to experimental animals have been tabulated by Mitchell[66] (Table 10, Appendix A). He has summarized some of the data collected by Lehman[53] relating to the dietary levels of pesticides that produced minimal or no effects after continuous feeding for 90 days to 2 years. Approximately the same dietary levels of chlorinated hydrocarbon insecticides and the organophosphorous insecticides were required to produce minimal or no effects. These levels are significantly lower than levels observed with the fungicides and herbicides which both required similar dietary levels.

Lehman[53] in his monograph has reviewed and summarized other information on pesticides in addition to the dietary levels that cause no effect. He has presented extensive data relating to mortality, body weight, organ weight, body storage levels, rate of disappearance, metabolism, reproduction effects, histopathology, neoplasms, and potentiating effects in dietary studies of specific pesticides with experimental animals.

Dale _et al_.[22] observed a direct correlation between the severity of symptoms and the brain concentration of DDT when rats were exposed to a single dose of DDT. Rats showing severe tremors had brain concentrations ranging from 386 to 483 ppm; those with convulsions, 289 to 606 ppm; and those with convulsions and death had DDT concentrations ranging from 524 to 848 ppm in the brain tissue. The animals that recovered from exposure to DDT (138 to 213 ppm) showed decreasing concentrations of DDT in the brain within 26 hours, accompanied by significantly increased levels in the fat (58 to 598 ppm) within 2 hours after exposure. The concentrations associated with death after one large dose were about the same as those following many smaller doses. The investigators' studies showed that in addition to the brain, all parts of the nervous system were affected, but indications were that the effects on the brain were the most important. The data indicated that, regardless of how the DDT was administered, the probability that death would occur was increased if concentrations of DDT in the brain exceeded 500 ppm in otherwise healthy rats or exceeded 200 ppm in debilitated rats.

Barnes and Heath[9] found that the oral toxicity of dieldrin in rats was increased when they were fed a restrictive diet leading to a loss of weight. In addition, rats that survived one dose of dieldrin remained much more sensitive than normal rats given a second dose within 3 weeks. That is, two equal doses given within 3 weeks of each other were more toxic than the same two given as a single dose. Heath and Vandeker[45] explained these results as due to the low solubility of dieldrin in water, its solubility in fat, and its mobilization in the body when fat is utilized. They concluded that the toxic effects of dieldrin were related to dieldrin mobilization, and that there was no need to postulate that dieldrin produced a long-lasting effect in the central nervous system.

Boyd and Chen[14] reported on lindane administered intragastrically to 103 young male rats fed a normal laboratory diet; the LD_{50} was found to be 157 ±37 mg/kg body weight. Death occurred within 1 to 25 hours from respiratory failure, usually following convulsions. Ninety rats whose growth had been stunted by feeding of a low protein (casein) diet from the time of weaning were twice as susceptible to the toxic effects of lindane as rats fed a normal diet. In other experiments with DDT, the LD_{50} for DDT was not affected in similar protein-deficient rats. These results suggested the possibility that lindane should be used with caution in areas where the diet of the population is deficient in protein. Wolfe et al.[109] observed that rats tolerated more than one-half an LD_{50} dosage of parathion daily for months if the insecticide was ingested through the day in the food. However, a daily dietary intake of one-nineteenth of an acute LD_{50} of dieldrin produced convulsions and death in some rats within a month. A possible explanation for these observations is that parathion, even at a high subfatal dosage, is excreted from the body in a few days, wheras dieldrin is stored and eliminated only very slowly.

Laboratory studies[109] have shown that rats are more susceptible to parathion than to endrin. However, meadow mice (Microtus) apparently are more sensitive to endrin and are relatively insensitive to parathion. It was observed that meadow mice populations practically disappeared when their habitat and food supply were sprayed once with endrin, but they were not noticeably affected when parathion was applied even several times during the year.

Evidence has been reported that some pesticides can undergo photochemical isomerization to yield products of different toxicity than the parent material. In one experiment,[34] dieldrin was exposed to sunlight (3 weeks to 2 months) or to a 2537 Å germicidal lamp (48 hours) and a photoconversion product was obtained which was approximately twice as toxic to the housefly and mosquito as dieldrin. In another study, a photoproduct of dieldrin was almost half as toxic for flies but approximately 4.5 times as toxic for mice than dieldrin.[84]

Street[89] observed that storage of dieldrin in the adipose tissue of female rats was markedly reduced when DDT and dieldrin were fed simultaneously. The amount of dieldrin present in the tissues of rats fed 1 and 10 ppm of dieldrin was reduced by the addition of 5 ppm DDT to the feed. The addition of 50 ppm DDT to the feed caused a 15-fold reduction in dieldrin storage in rats fed 1 ppm dieldrin and a 6-fold reduction in rats fed 100 ppm dieldrin. In a following study,[91] female rats were fed a diet for 10 weeks containing 0, 0.5 and 50 ppm DDT; 0, 50, and 500 ppm methoxychlor; 0, 1, and 10 ppm dieldrin, as well as a combination of these compounds at all dosage levels. Again it was found that dieldrin storage was markedly reduced when DDT was present in the diet. Storage of DDT when fed at the 50 ppm level was increased by the high dieldrin treatment. Methoxychlor storage was not affected by the other treatments; however, methoxychlor caused a small but significant reduction in the dieldrin storage. The DDE:DDT storage ratio in the tissue was not influenced by either dieldrin or methoxychlor. The DDT effect was postulated to result from enhanced dieldrin metabolism by liver microsomial enzymes.

Deichman et al.[25] studied the effect of aldrin and DDT on dogs. Six adult beagles in each of four groups were fed aldrin and/or DDT in capsule form five days a week for 10 months and then observed for an additional 12 months. The dogs were treated as follows:

Group 1: 0.6 mg of aldrin per kg body weight
Group 2: 24 mg of DDT per kg body weight
Group 3: 0.3 mg of aldrin plus 12 mg DDT per kg body weight
Group 4: Control

Hyperexcitability and tremors were noted in some dogs fed aldrin (Groups 1 and 3). The concentration of dieldrin in the fat, liver, and blood of dogs was the same strength as in an individual tissue, whether or not the animals had been fed aldrin and/or DDT (Groups 1 and 3). Retention of p,p'-DDT and DDE in fat and blood was roughly 2.5 to 4 times greater for Group 3 (aldrin plus DDT) than Group 2 which had been fed only DDT but at twice the concentration. The concentrations of p,p'-DDT and DDE in the liver tissue were similar in both Groups 2 and 3.

The possibility of two or more pesticides having an additive toxicity effect (potentiation) has been under investigation. Lehman[53] has referenced a number of findings in which potentiation has been observed in experimental animals. The potentiation effects of some pesticides have been reported as follows:

Diazinon: significant potentiation with malathion, and to a lesser degree with parathion, EPN, and systox in mice. No potentiation with other organophosphorous insecticides in dogs.

Carbaryl: no potentiation with other organophosphorous insecticides in rats.

Co-Ral: potentiation with piperonyl butoxide and malathion.

Guthion: no potentiation has been observed.

Delvon: some degree of potentiation with malathion in rats.

EPN: 10-fold increase in toxicity with malathion in rats, and a 50-fold increase with malathion in dogs.

Ethion: approximately a 3-fold increase with malathion in rats, and slight increase in dogs.

Ronnel: mild potentiation with malathion in rats.

One of the long-term effects of exposure to certain chemicals is the production of tumors, some of which are cancerous. The following pesticides have been listed by West[103] as suspected carcinogens: Aminotriazole, aramite, arsenic dithiocarbomates, DDT, aldrin, heptachor, dieldrin, endrin, 8-hydroxyquinoline, ethylene oxide, propylene oxide, and piperonyl compounds. However, the carcinogenic effects of pesticides have been observed in animals at relatively high concentrations and no carcinogenic effects have been observed at the concentrations found in ambient air.

2.3 Effects on Plants

Many of the insecticides and fungicides have been developed for use against pests on or near plant life. Therefore, these materials generally have no adverse effect on plant growth. Herbicides, however, have been developed specifically to prevent the growth of plants. They can be classed into two categories, selective (affecting only certain types of plants) and nonselective (affecting all types of plants). However, there are only quantitative differences for many herbicides in the two categories; many selective herbicides, when used in higher dosages, become nonselective.[66] The problems associated with the drift in the air of herbicides are discussed in Sections 3.3 and 4.

Many of the insecticides, although they do not affect the plant *per se*, have affected plant taste and flavor when used for food. Also, translocation of insecticides into the plant from the soil and the plant surface has been observed and studied.

Birdsall *et al*.[12] found undesirable flavor effects in some foods, especially after heat processing, resulting from treating the soil with insecticides. Undesirable flavors in food have been associated with specific insecticides as follows:

Aldrin: canned sauerkraut, cooked rutabagas

Endrin: canned beets, sauerkraut, squash, pumpkin, cooked rutabagas

Chlordane: canned potatoes, canned pumpkin

Heptachlor: canned sauerkraut, canned pumpkin

Hard and Ross[37] noted flavor changes in raw apples previously treated with methoxychlor, chlorbenzilate, and guthion; in canned apple juice from apples which had been treated with demeton; and in canned peaches from fruit treated with chlorbenzilate. Flavor changes, although not objectionable, were found in strawberries treated with kelthane, endrin, diazinon, heptachlor, chlordane, or aldrin; and in raspberrics treated with heptachlor, chlordane, or aldrin.

Mahoney[60] has reviewed this subject and presents many such examples of flavor changes. Lindane and BHC have imparted undesirable flavors to many foods: potatoes, sweet corn, carrots, green beans, turnips, onions, and squash. Problems have also arisen as a result of crop rotation; instances have occurred in which processed sweet corn had to be destroyed after being grown in fields which contained alfalfa the year before and had been treated with 0.5 lb of lindane per acre.

Lichtenstein[54] observed translocation of DDT, lindane, and aldrin into crops such as carrots, beets, cucumbers, potatoes, radishes, and rutabage. In another study,[57] carrots were grown in soils treated with abnormally high levels (5 lb/acre) of aldrin and heptachlor. Concentrations of insecticidal residues in the carrots varied from 22 to 80 percent of the concentrations in the soil.

The vertical distribution of the insecticidal residue within the carrot tissue corresponded to the distribution within the soil layers and most of the residue in the carrot (14 percent) was found in the outer thin layer of the peel. In another series of growth studies several different crops were grown in soils heavily treated with 5 and 25 lb/acre of heptachlor and of aldrin.[55] The insecticidal residues found in the crops are given in Table 11, Appendix A. It was concluded that under the normal low levels of treatment, none or only traces of insecticides in these crops would have been found. Additional data on this topic can be found in the review by Lichtenstein.[56]

2.4 Effect on Materials

There have been no reports of damage to inanimate materials from the pesticides *per se*, but some of the solvents used in spray application could have a damaging effect on paint and other surfaces.

2.5 Environmental Air Standards

The American Conference of Governmental Industrial Hygienists at their 29th Annual Meeting in 1967 set the threshold limit values for a number of chemicals used as pesticides.[76,98] These occupational values for an 8-hour workday are listed in Table 12, Appendix A. Foreign standards for some pesticides have been listed by Stern[88] and are listed in Table 13, Appendix A.

3. SOURCES

3.1 Natural Occurrence

Pesticides do not occur naturally in the atmospheric environment.

3.2 Production Sources

Following the introduction of DDT in 1945 there was a rapid increase in the production of synthetic organic pesticides. DDT production increased to 164 million pounds in 15 years. BHC production reached about 77 million pounds in 1950, which was about equal to the production of DDT that year. However, by 1963 the production of DDT had increased to about 179 million pounds and BHC production declined to 6.7 million pounds. Other organic pesticides, such as the herbicide 2,4-D, have increased in production continuously since they were first used as pesticides (Table 14, Appendix A). As a result of the increased production of organic pesticides, the production of arsenicals and other inorganic pesticides declined. Lead and calcium arsenate production totaled approximately 100 million pounds in 1939, whereas only about 8 million pounds are currently used (Table 14, Appendix A). In addition, there has been a considerable decline in the use of botanically derived materials, such as rotenone and pyrethrum. The use of the once popular nicotine sulfate has declined sharply.[44]

The sales of synthetic organic pesticides by type of use, volume, and value in the United States for 1964 to 1967 are presented in Table 15, Appendix A, and the production volume of major pesticides in Table 16, Appendix A.

The total production and sales of synthetic organic pesticides in the United States for the years 1962 to 1967 are shown in Table 17, Appendix A. The preliminary estimate for 1967 places production at slightly in excess of 1 billion pounds and the manufacturers' value at approximately 900 million dollars.[69] Total Unites States sales of pesticides in 1966, including inorganic as well as organic, amounted to over 1.25 billion pounds having a manufacturers' value of around 800 million dollars.[68] The annual growth rate in total sales value for the 1962 to 1967 period has averaged about 15 percent. This growth has been due in part to increased costs of production, but primarily to increased production volume and usage.

The manufacture, formulation, and packaging of pesticides present possible air pollution hazards. The pesticides are generally manufactured in closed systems of a continuous-process nature. The process systems are normally maintained at a slightly negative pressure to avoid leakage.[76] No data were found on the emission rates of pesticides from production plants. Tabor[95] sampled the air in a community (Fort Valley, Ga.) in which a formulating plant was operating. He noted that DDT concentrations in ambient air ranged up to 0.007 $\mu g/m^3$ during the spraying season (May-June) and 0.004 $\mu g/m^3$ when spraying season was over (September). He concluded that most of the DDT found in the air during September came from the formulating plant.

Production plant sites for pesticides are presented in Table 18, Appendix A.

3.3 Product Sources

The increased value of shipments during the last 10-year period represents primarily increased usage rather than merely increased costs. Table 19, Appendix A, presents the latest available survey (1964) for the overall farm usage of pesticides in the United States. Agricultural usage accounted for about 457.5 million pounds of pesticides (active ingredient basis), valued at about 500 million dollars. Of the total used, the fungicides, insecticides, and herbicides constituted approximately 90 percent of all pesticides.[71] The comparison of the farm use of selected pesticide chemicals with the production for 1964 is shown in Table 20, Appendix A. Approximately 42 percent of the total production was used by farmers; the remainder was used for export and domestic nonagricultural purposes.[71] Data showing the acreages in various land-use categories annually treated with insecticides are shown in Table 21, Appendix A. Approximately 5 percent of the land area of the United States (the 48 contiguous States) was treated with insecticides in 1962. Cropland and cropland pasture constituted more than 75 percent of the treated area, with cereal crops accounting for nearly 50 percent of the treated area in this category.[44]

The quantities of selected types of insecticide, herbicide, and fungicide ingredients used on crops in 1964 by geographical regions are presented in Tables 22, 23, and 24, respectively, in Appendix A. Crop insecticides were most heavily used in the Southern regions of the country. The three leading areas were the Southeast (35 million pounds), the Delta (27 million pounds), and the Southern Plains (20 million pounds).[71] Herbicide use was heaviest in the corn belt, which used approximately 25 percent of the total applied to crops. Other areas with large usage were the Northern Plains, Lake States, and Mountain regions.[71] The two regions which used the greatest amount of fungicides were the Southeast with 44 percent of the total, and the Pacific region with 26 percent of the total usage.[71]

The primary source of pesticide contamination of the environment is the process of application. Since much of this application is by spraying or dusting, some part of the quantity dispensed can remain in the atmosphere and be diluted and dispersed. However, under certain metorological conditions, dilution to an ineffectual concentration may not occur, and the chemical can drift in the air mass and cause adverse effects to nontarget forms of life some distance from the original application site.

Pesticidal sprays and dusts usually drift over relatively short distances. However, drift to streams and ponds or to land areas not intended to be treated has been common, particularly when application is by airplane. Moreover, drift from application with ground equipment also has occurred.[105] The reported presence of low levels of pesticides in fish and wildlife has been suggested as evidence of the persistance and the distribution of pesticides in the air.[101]

Many of the serious drift problems have occurred when chlorinated hydrocarbon pesticides were applied under proper conditions to fields or orchards adjacent to fields containing cattle forage but nevertheless drifted into the forage.[101]

Damage to cotton, cereal grain, tomatoes, and other broad-leaf plants has been caused by phenoxyherbicides such as 2,4-D as far as 15 miles from the site of application. The physical state of the pesticide (spray or dust), particle size, extent of the area being treated, as well as volatility of the herbicide should be considered when phenoxyherbicides are used. Highly volatile phenoxy-ester herbicides have been known to adversely affect sensitive crops some distance away from a treated area for a period of several weeks.[101]

Akesson and Yates[6] reviewed the pesticide drift literature and found that at least three factors affect a given application: (1) distribution equipment and method used, (2) the physical form (and formulation in cases of sprays), and (3) the microclimatology in the area. Generally, application by airplane tends to result in more drift than by ground equipment because, regardless of other factors, more control is possible with ground than with aerial equipment. Dusts have a greater tendency to drift than do sprays, to the extent that the Federal Government has banned the use of 2,4-D dusts. Akesson and Yates reported that a pesticide dust composed of particles 10 μ in diameter released about 10 feet above ground in a 3 mph wind drifted about 1 mile, and those with 2 μ particles drifted 21 miles, but a 50 μ droplet in a spray of the same pesticide drifted not more than 200 feet. The microclimatology is important in determining the movement and dispersion of the drift. Although drift of pesticides can be minimized by careful application in agricultural use, it was their belief that a certain amount of drift was unavoidable.

The potential of nonoccupational human acute poisoning resulting from the drift of pesticides should always be considered even though very few incidents of such poisonings have been reported. The TEPP poisoning episodes which occurred in Washington in 1963 have been discussed earlier (Section 2.1.4.3). Quinby and Doornink[73] in their discussion of these occurrences, emphasized that the same dusting procedures had been used for the previous 16 years in that area of the country; an infrequent combination of several factors had occurred, trapping the dust cloud in the air for periods long enough for people in the area of drift to breathe sufficient TEPP to cause shortness of breath. These factors were (1) thermal inversion and a static air condition for longer than an hour over a large area (2) topography of the land, causing interference with even a slow movement of the dust cloud and (3) tall growing crops with dense foliage, also interfering with air movement.

3.4 Other Sources

In addition to the production and large-scale agricultural uses of pesticides, there are other sources of pesticide air contamination. Pesticides are released into the atmosphere during application in public areas, buildings, and homes. Pesticides may be inhaled in dusts from treated soils, from house dust contaminated by applications for household pests, or from moth-proofed rugs, blankets, and clothes.[100] However, it is difficult at present to estimate the degree of importance to be placed on any of these sources as contributors to the concentration of pesticides in the ambient air, either locally or over a wide area.

For example, little is known about the concentrations that exist in the home and garden environment. The increased availability of pesticides for the home has led to increased usage each year. In 1963, the annual sales of aerosol pesticide canisters was reported to be one per household.[100] Although several fatalities resulting from inhalation of volatile pesticides in the home have been reported, nothing is known of the incidence of mild illnesses caused by home use of pesticides.[104]

Wolfe _et_ _al_.[110] observed that in the orchard and row-crop areas of the Pacific Northwest, many users destroyed burnable containers after the pesticide has been removed. The residual parathion in 12 paper bags that had each contained 4 pounds of powder was found to range between 0.25 and 1.20 g, with a mean of 0.60 g of the pesticide. Air samples were taken in the smoke from such burning bags and were found to contain 4,400 to 12,100 $\mu g/m^3$ of parathion, with a mean of 7,900 $\mu g/m^3$.

Harris and Lichtenstein[38] found in both laboratory and field studies that vapors toxic to vinegar flies and to houseflies were given off by soils treated with aldrin; heptachlor phorate; lindane; heptachlor epoxide; and dieldrin. They found no evidence that volatilization occurred with DDT, Sevin, and parathion. The volatilization rate of aldrin increased with increases in insecticide concentration in the soil, soil moisture, relative humidity of air passing over the soil, soil temperature, and rate of air movement over the soil. They concluded that volatilization of insecticidal residues from soil was a major factor in their disappearance.

Abbott and co-workers[2] presented the possibility that the air-soil contact might result in pesticides from the air being absorbed by the soil acting as a gas-solid chromatographic column, as well as by direct surface adsorption mechanisms. In addition, assuming a tendency to equilibrate, treated soils would lose pesticides and untreated soils would gain them.

Additional studies[56] revealed that cover crops such as alfalfa increased the persistence of volatile pesticides in the soil. In insecticide-treated soils, two or three times more insecticidal residues were recovered from alfalfa-covered plots than from fallow ones.

Hindin _et_ _al_.,[46] in studying the distribution of insecticides applied once to an irrigated plot, observed that DDT and ethion were not found in the air in detectable amounts prior to the application but were found in measurable quantities for as long as 2 weeks after application.

Acree _et_ _al_.[3] reported that codistillation of DDT and water can occur, and that approximately 50 percent DDT can be lost from a water solution in 24 hours by this means. Bowman _et_ _al_.[13] concluded from their studies that volatilization from soil surfaces may be an important pathway for loss of dieldrin and some other persistent organochlorine insecticides (p,p'-DDT, endosulfan, heptachlor, and lindane). These data also indicate this loss by codistillation might be diminished by organic matter in the soil. Spencer and Cliath[86] found in their studies that the vapor density associated with solid-phase dieldrin (HEOD) and dieldrin soil mixtures as measured by the gas saturation technique was 3 to 12 times greater than predicted from published vapor pressure values. Their measured vapor densities were 54 (20° C), 202 (30° C), and 676 (40° C) µg of HEOD per liter, the values being the same for dry HEOD as for HEOD plus water. The vapor density of HEOD in soil at 100 ppm was the same as that of HEOD alone, but at 10 ppm the vapor density in soil was reduced approximately 80 percent. The data indicated to Spencer and Cliath that the codistillation phenomenon does not result from an increased vapor density in the presence of evaporating water, and that loss of water is not required to attain maximum vapor density of HEOD, either in soil or above HEOD-water mixtures.

Wheatley and Hardman[107] observed increases in dieldrin residue levels in a plot of soil untreated with insecticide. They considered the possibility that rainfall could wash out quantities of dieldrin when present in the ambient air and account for the increase. Monthly samples of rainwater were collected in an area of central England

and analyzed for the presence of insecticides. The findings are presented in Table 25, Appendix A. Although the investigators detected small quantities of gamma-BHC, dieldrin, and p,p′-DDT in the rainwater, their conclusion was that these concentrations were insufficient to account for more than a small proportion of the pesticides present in the soil. However, the presence of organochlorine insecticides in the atmosphere and in rain would aid their dispersion in the environment and might partially explain the occurrence of residues in unexpected places.

The presence of organochlorine pesticide residues in rainwater was also observed by Abbott *et al.*[2] They collected monthly rainwater samples on roofs of two buildings approximately 1.45 km apart in central London. The quantities of organochlorine insecticides detected, based on detection limits of 5 parts per million-million for BHC and 10 parts per million-million for the other organochlorine insecticides, are presented in Table 26, Appendix A. These results suggested to them that the atmosphere carries, either as vapor or by occlusion on dust particles, small amounts of the organochlorine pesticides in common use in Great Britain, and that they are scrubbed out by rain and snow.

Evidence that pesticide-containing dust originating from soil can enter the ambient air, can be transported by air over long distances, and then can be precipitated to earth by rainfall, has been obtained by Cohen and Pinkerton.[19] They examined a sample of dust that had been deposited in the Cincinnati, Ohio, area on January 26, 1965, and that had as its origin a hugh dust storm in the Southern high plains of New Mexico and Texas. The movement of the dust-bearing air mass had been followed by meteorologists as it spread east and northeastward and passed over Cincinnati. A sample of the dust collected in Cincinnati was shown to contain seven identifiable pesticides: DDT and chlordane as the major pesticide components; lesser amounts of DDE and ronnel; and minor amounts of heptachlor epoxide, 2,4,5-T, and dieldrin (Table 27, Appendix A).

Storage and handling of pesticides presents a possible air pollution problem. Pesticides are usually stored in bags; glass, plastic, or metal bottles; or cans or drums. Contamination of the air may occur during handling, storage, or transit from breakage, leakage, or spillage.[76]

3.5 Environmental Air Concentrations

The role of air in the distribution of pesticides in the total environment has been of concern to many investigators. This interest has been stimulated by the need for information pertaining to the concentrations in ambient air of local, urban, and rural areas in which pesticides have been used in large quantities, as well as on the transport of pesticides for long distances remote from the site of actual application.

Batchelor and Walker[11] in 1954 obtained 94 air samples from various locations in an orchard where aerial parathion application operations were being carried on. The concentrations ranged from 0 to 100 μg/m³ in the orchard, 0-20 μg/m³ in the residential vicinities near the treated orchard, and trace amounts in residential vicinities far from the orchard. The highest concentrations were observed in the area of loading and mixing and ranged from a trace to 5,530 μg/m³. The dermal exposure under these conditions appeared to Batchelor and Walker to be considerably greater than the exposure by inhalation. Similar concentrations of parathion (ranging from 40 to 290 μg/m³, with a mean of 130 μg/m³) were found in a California orchard. Middleton[63] has cited early reports of as much as 360 μg/m³ of parathion in a Florida orchard (1951) and 20 to 150 μg/m³ in Canadian orchards (1952). Culver _et al_.[21] reported an air concentration level of about 3,300 μg/m³ near a worker handling malathion loading equipment. In the same report they observed an average concentration of 600 μg/m³ of malathion and 470 μg/m³ of chlorthion in a storage warehouse. Milby _et al_.,[65] in studying an outbreak of parathion poisoning among peach pickers, found that the ambient air samples at the breathing zone of the workers had a parathion concentration of 35 μg/m³.

Caplan et al.[17] obtained air samples in a small community of Planada, Calif. in 1955 while the entire area was being sprayed by airplane with malathion for mosquito control. The rate of application was 0.46 pounds per acre, and the spray particles had a mass-median diameter of 109 μ. Indications were that the air sampling measured only 12 percent of the insecticide, because the drop size was too large to be trapped by the sampler; however, the 12 percent probably represented the respiratory exposure. It was calculated that a man working in the open received a total respiratory exposure of 109.2 μg, or about five times greater than that of a man working in a building (23.5 μg). The outdoor skin exposure was 3,556 μg, or about four times the indoor exposure of 984 μg. The ambient air concentrations obtained during spraying are shown in Table 28, Appendix A.

Tabor,[95] in a series of studies in 1963 and 1964, found pesticides in the air of communities adjacent to agricultural areas where large quantities of pesticides are used on crops. The sampling was performed in the center of the community, and areas of spray application were generally at least a mile from the sampler. The samples were collected on glass fiber filters, and only particulate pesticide quantities could be determined. Therefore, the data represented minimum concentrations, and Tabor had no basis for estimating maximum values. His results are given in Table 29, Appendix A. He also sampled the air of four urban communities during insect control programs. Sampling was done within one-half mile of the fogging application. The results obtained are given in Table 29, Appendix A. A calculated possible respiratory intake of DDT was made for five of the communities.

Hindin et al.[46] studied the distribution of insecticides after one aerial application to an irrigated plot. They observed that no detectable levels of DDT or ethion were present in the air prior to application but were detected in samplings for as long as two weeks (Table 30, Appendix A) after application.

Bamesberger and Adams[8] collected air samples near Pulman and Kennewick Highlands, Wash. between April 16 and August 6, 1964, and examined them for aerosol and gaseous 2,4-D and 2,4,5-T herbicides. They collected 24-hour samples of air impinged on air impaction discs rotating through a n-decane collection fluid to retain the droplets of impacted aerosols. The gaseous fraction was collected in a modified midget impinger containing a two-phase n-decane and 3 percent aqueous sodium bicarbonate solution. Their data are presented in Table 31, Appendix A.

Detectable concentrations of particulate DDT were observed by Antommaria et al.[7] in the air in Pittsburgh.

Their sampling procedure divided the dust particulates into two size categories: The larger size dust (nonrespirable) that is trapped in the nasopharyngeal area, and the smaller particles (respirable) that deposit in the lower respiratory tract. These results are given in Table 32, Appendix A.

Abbott _et_ _al_.[2] sampled the air in London and its suburbs. Although the quantities of organochlorine insecticide residues detected were small (Table 33, Appendix A), their presence in air might be important.

The most recent and extensive program of monitoring the ambient air for concentrations of pesticides has been performed by the Midwest Research Institute (MRI) in 1967 to 1968 for the United States Food and Drug Administration.[64] Air monitoring stations were set up in nine localities in various sections of the United States: Baltimore, Md. (urban); Buffalo, N.Y. (rural); Iowa City, Iowa (rural); Salt Lake City, Utah (urban); Fresno, Calif. (urban); Riverside, Calif. (urban); Stoneville, Miss. (rural); Dothan, Ala. (rural); and Orlando, Fla. (rural). Air samples were obtained at each locality for 2 weeks out of each 4 weeks during the sampling period for a total of 6 months of sampling. The sampling units were designed to trap both particulate and gaseous pesticides in the air.

A summary of the MRI findings is shown in Table 34, Appendix A. The only pesticides that were found at all localities were p,p'-DDT and o,p'-DDT. Heptachlor epoxide, chlordane, DDD, and 2,4-D esters were not found in any samples; aldrin and 2,4-D were found in one sample each. Organophosphate pesticides were found only in samples from Dothan, Orlando, and Stoneville, methyl parathion at each of the three areas, parathion and malathion only at Orlando, and DEF (a cotton defoliant) only at Stoneville. Pesticide levels ranged from the lower limit of detection of 0.0001 $\mu g/m^3$ to a high of 2.52 $\mu g/m^3$. The pesticide levels that were found varied according to locality and season and generally were lower in urban areas than in agricultural areas. The highest levels were found in the rural areas of the South: Dothan, Orlando, Stoneville; relatively low levels were found in the other rural areas near Buffalo and Iowa City. The appreciable levels found in the urban area of Salt Lake City could be attributed to the mosquito control activity there; the levels were quite low in the other urban areas of Baltimore, Fresno, and Riverside. Higher levels had been anticipated in Fresno and Riverside, since both cities are surrounded by major agricultural activities, but the sampling may have been conducted too far from the spraying operations for higher concentrations of pesticides to be present in the air.

4. ABATEMENT

The abatement of pesticidal contamination of the ambient air is a complex problem but it is being attempted. It appears that the contamination arising from the production processes can be controlled. Although incidences of occupational poisonings have been reported (see Section 2.1.4.2), proper protective measures are available. Precautions similar to those used in general chemical industries are taken to prevent the dusts and fumes from leaving the production plant into the outside environment. Bag packers, barrel fillers, blenders, mixing tanks, and grinding operations are generally completely enclosed or hooded and the air is vented through baghouses or cyclone separators. Similar control procedures are used when liquids are involved; liquid scrubbers are used however, instead of baghouses.[5,23] Although Tabor[95] has monitored the air near a formulating plant and found air levels similar to that observed in earlier agricultural samplings in the same area, too little air monitoring data are available at the present time to properly evaluate the production air control measures.

The control of chemical drift as a source of pesticide air contamination has been studied extensively. Akesson and Yates[6] have reviewed the literature, including their own research on drift control. They considered that three factors affect the control of a given application: (1) the distribution equipment, (2) the physical state of the pesticide, and (3) the microclimatology of the area. Although the emphasis has been placed on control of aerial applications, applications made with ground equipment can also result in drift. However, greater operator control is possible with a ground unit, since it generally has a lower discharge rate than aerial equipment.

The physical state of the pesticide is quite important in drift. The drift potential from pesticide dust is very high because of particle size. Dust materials are generally screened to incorporate only particles ranging from 1 to 25 μ in size; on the average, 80 to 90 percent of the particles in the formulation are under 25 μ. Spray droplets of 50 μ in size show less drift than dusts of smaller particle size (see Section 3.3). Therefore, the use of dusts has been decreasing in recent years, and the Federal Government has banned the use of 2,4-D dust.[6]

MacCollom,[59] in a study of a Vermont apple orchard where Tedion dusting for apple insect control had been the standard practice for the previous 10 years, found that drift could be a problem even under ideal weather conditions. He noted that under conditions of a windspeed of 1.3 mph, a temperature of 81°F, and relative humidity of 40 percent, drift occurred up to 300 feet. He suggested that a buffer zone of at least 300 feet be used in future applications where forage areas are adjacent to the sprayed area.

Van Middelem[101] cited the work of Yoe, who found that spray droplets ranging from 10 to 50 μ in size can drift several miles from the area of application, whereas 100 μ-sized particles usually do not produce a drift hazard unless the winds are high. Akesson and Yates[6] in their review have cited the work of Brooks[15] on the relationship between particle size and anticipated drift pattern (Tables 35 and 36, Appendix A).

Evaporating the spray droplet in spraying operations has been considered as a drift control measure. Water is the most frequently used diluent because of its availability, its low cost, and its nonphytotoxic effects on agricultural crops. However, water droplets may experience considerable evaporation and reduction in size while airborne in the spray, resulting in a sufficiently smaller droplet size and therefore more drift than had been anticipated. As a control measure, oils which are relatively nonevaporative are frequently used as the pesticide carrier in sprays. They are especially used as carriers for low volume (1 to 3 gal/acre) applications of very fine sprays for forests and range lands.[6]

Improvement in delivery equipment and techniques is another partial solution to the abatement problem. Equipment has been developed for producing invert emulsions (water-in-oil emulsions) of which greater than 90 percent is in the water phase. In contrast to conventional oil-in-water emulsions, preparations containing a high water content are quite viscous. When using the invert emulsions, sprays consisting of large droplets can be delivered aerially, minimizing both drift and evaporation. Trials indicated that smaller quantities of pesticide could be used in the invert emulsion with equivalent results in terms of insect kill or herbicidal efficiency. At the same time, the accuracy of delivery was improved so that the invert emulsions could be applied under more adverse meteorological conditions than conventional sprays.[33]

Various spray nozzles have been designed and used with varied pesticide formulations having different viscosity, density, and surface tension in attempts to control drift during application. Additional factors such as the angle of the nozzle with airstream or the use of screens or discs at the nozzle also contribute to the characteristic of the spray. These factors are discussed in detail by Akesson and Yates.[6]

Meteorological conditions are extremely important parameters that are considered in the application of pesticides and the control of potential drifts. Wind direction and velocity, humidity and temperature at ground and higher levels, and the amount of sunshine or rain are all interrelated factors that are considered. Because of the importance of such meteorological information, the U.S. Weather Bureau provides this specialized data as part of their service. Dusting and spraying advisories are sent out on a teletypewriter circuit 24 hours a day emphasizing local weather conditions for aerial and ground applications for various agricultural chemicals. In addition, these advisories include information relating certain insect and other pest activities with weather conditions, so that pesticides can be applied at the proper time to produce maximum pest control.[81]

Volatilization of pesticides into the air from soil, water, plants, and other treated surfaces is known to occur. However, the control of this is complicated by the fact that the extent to which volatilization occurs is not known. Some control over volatilization from soil can be effected by the use of cover crops. It has been observed that two to three times more insecticidal residues were recovered from alfalfa-covered plots than from fallow ones.[56]

5. ECONOMICS

The economic and social benefits gained by the use of pesticides are great, as noted in a number of discussions. The President's Science Advisory Committee[100] reported that modern agricultural efficiency is maintained only through the use of pesticides. It has been estimated that without the use of pesticides, 50 percent of the agricultural and forestry crops of California would be destroyed, and that the present loss in spite of pesticides is 21 percent.[75] In the United States, agricultural losses from insect damage have been estimated at approximately 3.5 billion dollars, losses from plant diseases at 2.9 billion dollars, and losses from weeds at 3.7 billion dollars; the annual total worldwide damage by pests to agriculture has been estimated to be about 80 billion dollars.[62] In addition, pesticides have contributed to the eradication or reduction of a number of human diseases such as malaria, typhus, and yellow fever in less developed countries of the world.[44,100] However, the estimate for worldwide malaria is still placed at about 200 million cases and 2.5 million deaths a year.[62]

Insect-borne diseases have been highly prevalent in the past in the United States. However, largely because of the introduction of DDT and other synthetic organic insecticides, the number of deaths (Table 37, Appendix A) and number of reported cases (Table 38, Appendix A) for some of these diseases have declined considerably. Malaria at one time had a severe economic impact on the Southern States in the United States, but today it is almost nonexistent.[44]

The economic benefits derived from the use of pesticides by agriculture in the United States have been quite significant. These benefits have been not only in increased yields of production, but also in increased quality of the product. In many cases, the improvement in quality has been such that a high percentage of the crop would not have been otherwise marketable. In California, for example, in crops not treated with insecticides the percent of wormy fruit in 1956 was 21 to 23 percent, but it was only 0.5 percent following the use of guthion.[44] Some examples of increased crop yields from use of insecticides, herbicides, and fungicides are presented in Tables 39, 40, and 41 in Appendix A. Although the value may vary for different crops and regions of the country, it has been estimated that nationally about five dollars are saved for every dollar invested in chemical pesticide usage. The pesticide cost includes research, development, and price of the material.[75] Data on the production, sales, and usage of pesticides are presented in Section 3.

No tabulated data on costs of damage due to air pollution from pesticides have been found in the literature. However, episodes of death or harm to livestock and damage to crops caused by pesticide drift resulting from agricultural treatment have been reported (see Section 3.3). Akesson and Yates[6] have reported that many lawsuits have arisen from such episodes and that liability insurance has been made available to operators of pesticide equipment.

The costs of pesticide damage to wildlife resulting from air pollution is impossible to estimate. The direct effects of such pollution on wildlife, if compared with those on livestock, are probably small. However, the indirect effects on the entire ecosystem resulting from the presence of pesticides in the air might be greater. However, at the present time, insufficient information exists regarding the translocation of pesticides in the ecosystem to make any valid cost estimates or conclusions.

The economic costs of pesticide contamination of the air with respect to human health have not been estimated. While there have been reported episodes of death or illnesses resulting from respiratory exposure to pesticides, it is not known how many unreported illnesses may occur. The percentage of the body burden of DDT resulting directly from respiratory exposure probably is low (Campbell _et al._[16] have estimated it to be about 0.06 percent) but the percentage that is indirectly due to overall environmental pesticide pollution is not known.

Furthermore, outside of those costs estimated for agricultural damage, there appears to be no cost figures available for controlling air pollution by pesticides from manufacturing or formulating plants.

6. METHODS OF ANALYSIS

The analytical procedures for the determination of pesticides in the environment generally involve four steps: (1) a sampling method that collects a sufficient quantity of the material to permit analysis, (2) an extraction procedure to remove the specific pesticide(s) from the bulk of nonpesticide environmental material, (3) separation or "cleanup" to remove nonpesticidal interfering materials carried along during the extraction, and (4) detection and identification. The analysis of pesticides has been handicapped by the low concentrations present in the ambient air, which in the past have made the completion of the above four steps difficult. Only in recent years has instrumentation become sufficiently sophisticated, especially for detection and identification, so that valid information may be obtained. Table 42, Appendix A, presents the analytical sensitivity which has been acquired over the years as understanding of the pesticide residue subject has increased.

6.1 Sampling Methods

In addition to the low concentration of airborne pesticides, sampling is also complicated by the coexistence of nonpesticidal materials in both aerosol and vapor phases.

A sampling method has recently been developed by the Midwest Research Institute[64] using a three-section sequential collection train consisting of (1) a glass cloth filter, (2) an impinger containing 2-methyl-2,4-pentanediol and (3) an adsorption tube containing alumina. The maximum air sampling rate is approximately 29 liters/minute, and about 24 hours are generally required to collect enough sample for analysis.

Tabor[95] sampled only particulate DDT by the collection of particulate samples on glass-fiber filters. In another study, air samples were collected at rooftop level in Pittsburgh with a two-stage sampling system to separate airborne dust into two fractions.[7] The large particles were collected by sedimentation on 71 horizontal trays, and particles which penetrated through this section of the sampler were collected on an MSA 1106B glass-fiber filter. Each sample of particulates was obtained by continuous sampling at an average flow rate of 1.22 m^3/min.[7]

An air sampling system for the differential collection of aerosol and gaseous fractions of airborne herbicides has been reported.[8] It consists of a rotating disk impactor for collecting aerosol droplets down to approximately 3 μ in diameter, followed by a midget impinger to collect the gaseous fraction. The impactor was specially designed and constructed of glass, Teflon, and stainless steel to prevent contamination of the collection fluid with substances that interfere with electron capture gas chromatography. Incoming air impinges on the impaction disk that rotates slowly through a fluid well containing n-decane. The impacted droplets wash off into the collection fluid. The disk then passes through a Teflon squeegee to remove the adhering droplets, thus presenting a smooth surface containing a fluid film upon which the air stream impinges.

There are other sampling techniques used to measure operators' hazards in the field. The level of exposure may be determined by the amount of toxicant trapped on the filter of a respirator worn by the operator. Samples are also collected in a special respirator which is modified to simulate nasal breathing characteristics. Contact samples are collected on pads attached at suitable points on the operators' clothing. Additional samples may be taken by means of suction-operated equipment placed in the breathing zones. The mass to size ratios of airborne particles are evaluated by sampling the air in the breathing zones through cascade impactors and also by collecting the fallout on slides set at different heights in the working area.[58]

Air samples were collected at tractor operators' breathing zones using all-glass fritted absorbers and electric or hand-operated suction pumps. Exposures were also determined by attaching filter pads to double-unit respirators.[49]

6.2 Quantitative Methods

Although methods have been developed to determine the concentration of some pesticides or a component of the pesticide, e.g. phosphorus, the methods are very tedious and time consuming. More research is needed to reduce the methods to procedures that can be used economically for routine analyses in the National Sampling Network.

6.2.1 Extraction and "Cleanup"

The collected pesticide must be extracted from the particulate matter and generally needs a "cleanup" treatment to remove other interfering substances before the final analysis can be performed.

The extraction and "cleanup" procedure for the Midwest Research Institute sampling train[64] is as follows: The filter cloth is washed with methanol. The alcoholic mixture is poured over an alumina adsorbent which has previously been transferred to a chromatography tube. The treated alumina column is extracted with hexane. The impinger solution (2-methyl-2,4-pentanediol) is diluted with water and this solution is extracted with hexane. The combined hexane extracts are concentrated by evaporation. The treated hexane solution is passed through a Florisil column and the pesticides eluted from the column by first adding 0.5 percent dioxane in hexane to remove the chlorinated hydrocarbon pesticides followed by 5.0 percent dioxane in hexane to remove the organophosphate pesticides. The two solutions are concentrated before final analysis by gas chromatography.

Tabor[95] used pentane followed by benzene to extract chlorinated and thiophosphate pesticides from particulate matter. The residues of extracts were analyzed by gas chromatography without further treatment.

6.2.2 Detection and Identification

Pesticide analysis is generally accomplished by some form of chromatography. Three types of chromatography can be used for the quantitative determination of pesticide residues: (1) gas chromatography, (2) thin-layer chromatography, and (3) paper chromatography. The gas chromatographic technique has been used to separate complex pesticide mixtures in a single operation.

A highly sensitive detector for chlorinated pesticides is the electron-capture detector. It is capable of measuring some chlorinated pesticides in concentrations as low as the nanogram range (10^{-9} g). Another detector widely used with gas chromatography of chlorinated hydrocarbons is the microcoulometric detector. This detector operates on the following principles: (1) As each chlorinated pesticide emerges from the chromatographic column, it passes through a combustion tube where the pesticide is burned with oxygen to yield hydrogen chloride, water, and carbon dioxide. (2) The gas stream then flows through a titration cell containing silver ion, which is maintained electrochemically at a constant concentration. (3) Hydrogen chloride precipitates the silver ion stoichiometrically, and the current required to regenerate it from a silver electrode is recorded as a chromatographic peak. The detector can measure as little as 10^{-8} g of chlorine or sulfur. Other detectors that have been used include hydrogen flame detectors (sensitive to carbon-containing compounds), sodium thermionic detectors (sensitive to thiophosphates), and flame-photometric detectors (sensitive to phosphorus).

The Midwest Research Institute[64] method of analysis uses gas chromatography. The chlorinated pesticides were determined by using two different columns with an electron-capture detector. The organophosphate pesticides were determined by using two different columns with a flame photometric detector.

Tabor[95] used an electron-capture detector and a sodium thermionic detector for determining chlorinated and thiophosphate pesticides.

A summary list of major analytical instrumentation or techniques is presented in Table 43, Appendix A.

Westlake and Gunther[106] have reviewed detection systems used in pesticide residue evaluations. Table 44 (Appendix A) lists the available systems and the minimum detectability of each. Detectability as used in the Table refers to Suthle Sutherland's[94] definition; the detectable level is the concentration of pesticide above which a given sample of material can be said, with a high degree of assurance, to contain the chemical analyzed. Westlake and Gunther[106] in their review have discussed each of the available methods, including illustrations of the devices and literature references to their use. Also included are a table listing more than 100 pesticides for which infrared spectra have been published, and a table listing more than 50 pesticides for which mass spectal data have been published.

6.2.3 Other Quantitative Methods

Thomson and Abbott[97] described two methods termed Chemical Group Analysis and Biological Test Methods.

(1) Chemical Group Analysis. By comparison with a certain class of substances, the pesticide can be identified and determined. This method does not give precise identification and cannot be applied without purification of the extracted material.

Organophosphorous Pesticide Residues. In applying the Chemical Group Analysis technique to these residues, phosphorus is usually determined quantitatively, not the pesticide compound. The essence of the method is the extraction and "cleanup" of the residue to insure the absence of natural phosphorous compounds. The phosphorous in the subdivided extract is eventually converted to phosphoric acid by wet oxidation. The subsequent addition of ammonium molybdate and reduction with stannous chloride produces a heteropoly blue color which is compared against standards produced from solutions of known phosphorous content. This method has only limited selectivity and is sensitive down to 5 μg of any one pesticide, i.e., 0.1 ppm in a 50-g sample. A simple screening method for the rapid estimation of organophosphorous pesticides using the above chemical-end-method of analysis has recently been introduced. In this method the compounds are extracted from the sample, "cleaned up" on a silica gel chromatoplate, and oxidized with ammonium persulfate or a nitric-perchloric acid mixture for phosphorous determination. Colorimetric and esterase-inhibition methods of estimating total phosphorous have been used to develop a method of automatic wet chemical analysis.

Chlorinated Pesticide Residue. In the analysis of this type of residue, the pesticides are extracted and after a limited "cleanup" process, they are spotted onto a filter paper flag, which is burned in a flask of oxygen. The chloride formed is absorbed in dilute sulfuric acid and can be estimated colorimetrically by the addition of ferric ammonium sulfate and mercuric thiocyanate; the sensitivity of this method of estimation is approximately 5 μg of organo-chlroine pesticide. A more sensitive method is to measure the quantity of chloride produced potentiometrically. This makes the method sensitive down to 0.5 μg of pesticide. Recently a new continuous chloride ion system has been developed for use with a completely automated combustion apparatus to determine organochlorine pesticides and their residues.

(2) Biological Test Methods. These methods show the presence or absence of toxicologically significant residues. They are basically useful as sorting methods or for confirming the presence of pesticide residues. The basis of the bioassay methods is the comparison of the response of selected insects to pretreated or unknown samples with the insects response to

a series of standard pesticides under the same test conditions. These methods are very sensitive and can easily detect pesticide levels of 0.1 ppm, but the methods do not distinquish between pesticides of similar toxicity. Some of the common insects and other organisms that are used in such bioassays are vinegar fly, housefly, mosquito larvae, mites, brine shrimp, daphnia, guppies, and goldfish.[93]

7. SUMMARY AND CONCLUSIONS

Pesticides include a spectrum of chemicals used to control or destroy pests which may cause economic damages or present health hazards. These are employed in agriculture, forestry, food storage, urban sanitation, and home use. Since hundreds of such chemicals are presently available, this report has been limited to those synthetic organic pesticides which currently are used in the greatest volume and are potential health hazards to humans, domestic and commercial animals, and fish and wildlife because of the pesticides, inherent toxicity or persistence.

Pesticides can cause poisoning by ingestion, absorption through the intact skin, or inhalation. In cases of accidental occupational poisonings, it has usually been impossible to determine if the exposure was predominantly respiratory or dermal. Of the 111 accidental deaths caused by pesticides in 1961 in the United States, five deaths were attributed to respiratory exposure.

Of all the pesticides, the chlorinated hydrocarbon and organophosphorous insecticides are of major concern because of their health hazard. The acute toxicity of the organo-phosphates, on the average, is somewhat greater than that of the chlorinated hydrocarbons. However, the latter group is considerably more persistent because of their greater stability.

Some members of the chlorinated hydrocarbon group—especially DDT, dieldrin, and BHC—have been found as residues in human fat tissue in all parts of the world. The mean storage level of DDT in the body fat of the general population in the United States in 1961 to 1962 was reported to be 12.6 ppm. The dieldrin and BHC storage levels have been reported in the United States as 0.15 ppm and 0.2 ppm, respectively.

Acute poisonings of commercial and domestic animals have usually been accidental and involved the more toxic organophosphorous insecticides. Animals also store the chlorinated hydrocarbon residues in fat tissue, and as with humans, the significance of this storage is not completely known. When ingested, as little as 7 to 8 ppm of DDT residue on hay will result in 3 ppm being excreted in cow's milk, and butter made from such milk will contain 65 ppm.

Fowl, fish, and many forms of wildlife have been adversely affected by pesticides, especially the chlorinated hydrocarbons. Birds are affected by DDT resulting in thin-shelled eggs and a decrease in hatchability. Wildlife in general have been affected in various parts of the country.

Herbicides may cause damage to other than the target plants if the dosage is too great. Some insecticides have produced undesirable flavors in plants used as food. Translocation of DDT and other insecticides into crops from the soil has been observed, but apparently this does not result in a high residue level.

There have been no reports of damage to inanimate materials from the pesticides as such, but some of the solvents used in spraying applications could have a damaging effect on paint and other surfaces.

The annual growth rate in total sales value for the 1962 to 1967 period has averaged about 15 percent. This growth has been due in part to increased costs of production, but primarily to increased production volume and usage. The preliminary estimate for 1967 places production at slightly in excess of 1 billion pounds, and the manufacturers' value at approximately 900 million dollars.

Agriculture is the leading user of pesticides in the United States. Approximately 5 percent of the land area of the United States (the 48 contiguous States) was treated with insecticides in 1962. Cropland and cropland pasture constituted more than 75 percent of the treated area.

The primary source of pesticides in the air is the process of application. Even under the most ideal conditions, some amount will remain in the air following the application. However, under certain meteorological conditions, the pesticide spray or dust does not settle and can drift some distance from the area of application. Many episodes have occurred in which these drifting pesticide clouds have caused inhalation poisonings as well as toxic residues on croplands.

It is known that pesticides will volatilize into the air from soil, water, and treated surfaces. It has also been observed that rain and snow can wash pesticides from the air back to soil and water surfaces. There is good evidence that pesticide-containing dust originating from soil can enter the ambient air and be transported for considerable distances before falling back to the earth. The full significance of this with respect to effects on the total environment is still not known.

Home use of pesticides has been increasing annually, but little is known about the concentration of pesticides in the home.

The air near agricultural areas being treated with pesticides has been monitored and the specific pesticides being used were detected. Detectable amounts of DDT and related insecticides also have been found in the air over urban areas. It has been only recently that an air monitoring network for pesticides has been established so that sufficient data will become available to ascertain the magnitude and dispersion of pesticides in the ambient air. Preliminary data from nine areas sampled have shown that seasonal and regional variations of pesticide concentrations in the air exist and that the only pesticide common to all of the sampled areas was DDT.

The abatement and control measures for prevention of air contamination employed by the chemical industry in general are used in pesticide production facilities. The major problem in pesticide air pollution abatement is in control of pesticide drift during application. This problem is being approached by improvement in application equipment and methods, improvement in pesticide formulation and physical properties, and more extensive consideration of micrometeorological data.

The economic and social benefits gained by the use of pesticides have been great. Pesticides have contributed to the eradication or reduction of a number of human diseases both in the United States and in other parts of the world. It has been estimated that nationally about five dollars are saved for every dollar invested in chemical pesticide usage. Although episodes of damage caused by pesticide drift resulting from agricultural treatment have been reported, no tabulated data on costs of damage due to air pollution from pesticides have been found. The costs of pesticide air pollution damage to humans, wildlife, and other animals cannot be estimated.

The analytical procedures for the determination of pesticides in the environment generally have involved four steps: sampling, extraction, separation, and detection. These procedures have been handicapped in the past by the low pesticide concentrations that must be measured in the ambient air. However, in recent years significant advances have occurred in instrumentation for detection and analysis of low concentrations.

Based on the material presented in this report, further studies are suggested in the following areas:

(1) Development of better sampling and analysis methodology and standardization for internal consistency.

(2) Further determination of concentrations of pesticides in the atmosphere for a clearer definition of pesticide pollution, not only in known contaminated areas but also on a large geographical scale.

(3) Further investigation of the translocation of pesticides from the soil and water to the air and return.

(4) Investigation of the ambient air pesticide levels in the home and determination of individual misuse of pesticides causing contamination of the home environment.

(5) Expansion of research on biologic pest controls.

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APPENDIX A

TABLE 1

EXPOSURE OF WORKERS TO PESTICIDES WHILE CARRYING OUT VARIOUS ACTIVITIES[28]

Compound	Activity	Exposure		
		Dermal (μg/man/hr)	Respiratory (μg/man/hr)	Total (percentage of toxic dose per hour)[a]
Parathion	Spraying apples	77,700	200	5.4
Chlorothion	Applying aerosol	3,000	300	0.003
Malathion	Applying aerosol	6,600	300	0.003
Guthion	Checking cotton	5,400	b	0.004
Methyl parathion	Checking cotton	700	b	0.002
DDT	Spraying apples	274,000	120	0.15
DDT	Indoor house spraying	1,755,000	7,100	1.02

(continued)

TABLE 1 (Continued)

EXPOSURE OF WORKERS TO PESTICIDES WHILE CARRYING OUT VARIOUS ACTIVITIES

Compound	Activity	Exposure		
		Dermal (μg/man/hr)	Respiratory (μg/man/hr)	Total (percentage of toxic dose per hour)[a]
DDT	Spraying house outside	243,000	110	0.14
DNOC	Spray thinning of apples	63,200	400	0.25
DNOSBP	Applying as herbicide	88,700	120	0.57

[a] Calculated for a 70 kg man on the basis of dermal LD to male white rats or guinea pigs.

[b] Value obtained was below experimental limits of chemical method.

APPENDIX A

TABLE 2

OCCUPATIONAL DISEASES ATTRIBUTED TO PESTICIDES AND OTHER AGRICULTURAL CHEMICALS IN CALIFORNIA, 1953-1963[104]

Year	All Industries	Agriculture	Other Industries*
1953	377	277	100
1954	391	248	143
1955	531	326	205
1956	789	464	325
1957	749	434	315
1958	910	599	311
1959	1,093	782	311
1960	975	668	307
1961	911	578	333
1962	827	545	282
1963	1,013	746	267

*Includes service, construction, manufacture, government, etc.

APPENDIX A

TABLE 3

OCCUPATIONAL DISEASES ATTRIBUTED TO PESTICIDES AND OTHER AGRICULTURAL CHEMICALS IN CALIFORNIA, 1953-1963[104]

Year	Total All Conditions	Systemic Poisonings			
		Phosphate Ester Pesticides	DDT, Lindane, Endrin, Dieldrin	Other Agricultural Chemicals	Total
1953	377	146	9*	46	201
1954	391	101	1*	20	182
1955	531	126	4*	53	183
1956	789	197	11	73	281
1957	749	189	12	51	252
1958	910	227	14	87	328
1959	1,093	407	10	82	499
1960	975	283	7	78	368
1961	911	194	14	60	268
1962	827	140	21	58	219
1963	1,013	267	14	64	345
Total	8,566	2,277	117	672	3,066

*DDT only.

APPENDIX A

TABLE 4

ESTIMATED ANNUAL RELATIVE CONTRIBUTION OF VARIOUS ENVIRONMENTAL SOURCES TO THE BODY BURDEN OF DDT PLUS DDE[16]

	Source				
	Air	Water	Food	Other	Total
Concentration	2×10^{-4} $\mu g/m^3$	0.02 ppb	0.08 ppm		
Intake	13×10^3 m^3	364 liters	560 kg		
Total Intake	30 µg	10 µg	44,800 µg	Approx. 5,000 µg	Approx. 50,000 µg

APPENDIX A

TABLE 5

IDENTITY OF PESTICIDES RESPONSIBLE FOR ACCIDENTAL DEATHS IN THE UNITED STATES IN 1956 AND 1961[42]

Pesticide	1956	1961
Inorganic and botanical solid and liquid pesticide		
Arsenic	54	29
Thallium	8	2
Mercury		1[a]
Phosphorous	21	12
Fluorides		6
Sodium chlorate	1	
Calcium polysulfide		1
Boric acid	1	
Cyanide (solid)		3
Copper oleate mixed with tetrahydronaphthalene	1	
Strychnine	3	1
Nicotine	4	3
Pyrethrum	1	
Camphor	1	
Rotenone, copper, and sulfur	1	
Subtotal	96	58
Organic phosphorus insecticides		
Diazinon	2	1
Demeton	1	
Malathion	3	3
Methyl parathion		3
Parathion	11	15
Mevinphos		1
TEPP	2	
Unspecified organic phosphorus insecticides	1	1
Subtotal	20	24

(continued)

APPENDIX A

TABLE 5 (Continued)

IDENTITY OF PESTICIDES RESPONSIBLE FOR ACCIDENTAL DEATHS IN THE UNITED STATES IN 1956 AND 1961

Pesticide	1956	1961
Chlorinated hydrocarbon insecticides		
Aldrin	1	
BHC (including lindane)	2	1
Chlordane	3	
DDT	1	
Dieldrin	1	1[a]
Endrin	3	1
Toxaphene	1	2
Combination of chlorinated hydrocarbon insecticides	1	1
Subtotal	13	6
Solids and liquids (E870-E888) (pesticides only)		
Formaldehyde	1	
Combination of specified insecticides		4[b]
2,4-D		1
Warfarin	1	1[b]
Coumarin		1
Isobornyl thiocyanoacetate	1	1
Unspecified insecticides	7	6[a]
Unspecified rodenticides	6	3
Subtotal	16	17

(continued)

APPENDIX A

TABLE 5 (Continued)

IDENTITY OF PESTICIDES RESPONSIBLE FOR ACCIDENTAL DEATHS IN THE UNITED STATES IN 1956 AND 1961

Pesticide	1956	1961
Gases and vapors (E890-E895) (pesticides only)		
Carboxide gas[c]		1
Cyanide gas	1	3[a]
Ethylene dibromide		1
Mercury	2	
Methyl bromide	3	
Sulfur dioxide	1	1
Subtotal	7	6
Grand Total	152	111

[a] Diagnosis of pesticide poisoning open to serious question.

[b] Diagnosis of pesticide poisoning open to some question.

[c] Mixture of ethylene oxide and carbon dioxide.

APPENDIX A

TABLE 6

DISTRIBUTION OF ACCIDENTAL PESTICIDE DEATHS IN THE UNITED STATES IN 1961[42]

	Age Group				
Parameter	<10	10-19	20-69	≥70	Total
Occupational					
Yes	0	4	12	1	17
No	57	4	24	2	87
Unknown	0	0	7	0	7
Total	57	8	43	3	111
Route of exposure					
Oral	47	3	27	3	80
Respiratory	1	1	3	0	5
Dermal	1	0	0	0	1
Combined	5	3	9	0	17
Unknown	3	1	4	0	8
Total	57	8	43	3	111

APPENDIX A

TABLE 7

ACCIDENTAL DEATHS ATTRIBUTED TO PESTICIDES AND OTHER AGRICULTURAL CHEMICALS IN CALIFORNIA, 1951-1963[104]

	Children		Workers		
Year	Total	Organic Phosphates	Total	Organic Phosphates	Total
1951	3	0	0	0	5
1952	5	0	1	0	6
1953	4	1	4	3	10
1954	9	4	2	1	12
1955	3	0	1	0	6
1956	11	1	4	0	18
1957	8	1	2	1	12
1958	6	0	3	1	13
1959	10	2	5	1	18
1960	4	0	0	0	4
1961	3	0	3	2	6
1962	4	2	1	1	5
1963	3	1	1	1	6
Total	73	12	27	11	121

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TABLE 8

EFFECT OF METHOD OF ADMINISTRATION ON APPEARANCE OF DDT AND ITS METABOLITES IN MILK[108]

Method of Administration	Consecutive Days Dosed	Mean Maximum Response* (ppm in milk fat)			
		DDT	DDE	DDD	Total
Intratracheal	1	0.68	0.06	0.0	0.74
	6	1.54	0.01	0.08	1.64
Oral (capsular)	1	0.59	0.0	0.28	0.87
	6	0.49	0.08	1.18	1.75
Oral (aged residue)	1	0.38	0.90	0.56	1.84
Intravenous	1	3.00	0.12	0.12	3.24
	6	7.60	0.25	0.68	8.53

*Average of three cows. Net gain over base line.

TABLE 9

ACUTE ORAL AND DERMAL LD_{50} VALUES OF INSECTICIDES FOR WHITE RATS[92]

Insecticides	Oral LD_{50} (mg/kg)		Dermal LD_{50} (mg/kg)	
	Males	Females	Males	Females
Chlorinated Hydrocarbon Insecticides				
Aldrin	39	60	98	98
Benzene hexachloride	1,250			
Chlordane	335	430	840	690
Chlorobenzilate	1,040	1,220		>5,000
DDT	113	118		2,510
Dichloropropane-Dichloropropene	140[a]		2,100[a,b]	
Dicofol	1,100	1,000	1,230	1,000
Dieldrin	46	46	90	60
Endosulfan	43	18	130	74
Endrin	17.8	7.5	18	15
Ethylene dibromide	146	117	300[a,b,c]	
Ethylene dichloride	770[a]		3,890[a,b]	
Heptachlor	100	162	195	250
Kepone	125	125	>2,000	>2,000
Lindane	88	91	1,000	900
Methoxychlor	5,000	5,000		>6,000
Mirex	740	600	>2,000	>2,000
Paradichlorobenzene	>1,000	>1,000		
Perthane	>4,000	>4,000		
Strobane	200[a]		>5,000[a,b]	
TDE	>4,000	>4,000	>4,000[a,b]	
Telone	250-500[a]			
Toxaphene	90	80	1,075	780
Organic Phosphate Insecticides				
Abate	8,600	13,000	>4,000	>4,000
Azinphosmethyl	13	11	220	220
Azodrin	17.5	20	126	112
Bidrin	22[a]		225[a,b]	
Carbophenothion	30	10	54	27
Ciodrin	125[a]		385[a,b]	
Coumaphos	41	15.5	860	
Demeton	6.2	2.5	14	8.2
Diazinon	108	76	900	455

(continued)

APPENDIX A

TABLE 9 (Continued)

ACUTE ORAL AND DERMAL LD_{50} VALUES OF INSECTICIDES FOR WHITE RATS

Insecticides	Oral LD_{50} (mg/kg)		Dermal LD_{50} (mg/kg)	
	Males	Females	Males	Females
Organic Phosphates Insecticides				
Dichlorvos	80	56	107	75
Dimethoate	215		400	610
Dioxathion	43	23	235	63
Disulfoton	6.8	2.3	15	6
EPN	36	7.7	230	25
Ethion	65	27	245	62
Fenthion	215	245	330	330
Malathion	1,375	1,000	>4,444	>4,444
Methyl parathion	14	24	67	67
Methyl trithion	98	120	215	190
Mevinphos	6.1	3.7	4.7	4.2
Naled	250		800	
Nemacide	270			
Parathion	13	3.6	21	6.8
Phorate	2.3	1.1	6.2	2.5
Phosphamidon	23.5	23.5	143	107
Ronnel	1,250	2,630		>5,000
Ruelene	635	460		
Tepp	1.05		2.4	
Trichlorfon	630	560	>2,000	>2,000
Carbamate Insecticides				
Carbaryl	850	500	>4,000	>4,000
Zineb	>5,000	>5,000	>2,500	>2,500
Other Insecticides				
Binapacryl	63	58	810	720
Calcium arsenate		298		2,400
Cryolite	200^{a}			
DN-111	330^{a}		>1,000^{a,d}	
Lead arsenate		1,050		>2,400
Methaldehyde	Ca 1,000^{a,e}			
Morestan	1,800	1,100	>2,000	>2,000
Naphthalene	2,400	2,400	>2,500	>2,500

(continued)

APPENDIX A

TABLE 9 (Continued)

ACUTE ORAL AND DERMAL LD_{50} VALUES OF INSECTICIDES FOR WHITE RATS

Insecticides	Oral LD_{50} (mg/kg)		Dermal LD_{50} (mg/kg)	
	Males	Females	Males	Females
Other Insecticides				
Nicotine sulfate		83		285
Ovex	2,050[a]			
Paris green		100		>2,400
Pyrethrins	>1,500[a]		>1,880[a,b]	
Rotenone	50-75[a]		>940[a,b]	
Ryania	1,200[a]		>4,000[a,b]	
Tetradifon	>14,700[a]		>10,000[a,b]	

[a] Sex not indicated.
[b] Value for rabbits.
[c] Approximate LD_{50}.
[d] Value for guinea pigs.
[e] Value for dogs.

APPENDIX A

TABLE 10

TOXICITY OF SELECTED PESTICIDES[66]

(Dietary levels measured in ppm producing minimal or no effect after continuous feeding for 90 days to 2 years)

Pesticide	Toxicity	
	Rats	Dogs
Chlorinated Hydrocarbon Insecticides		
Cyclodiene compounds		
Aldrin	0.5	1
Chlordan	25	a
Dieldrin	0.5	1
Endosulfan	30	30
Heptachlor	0.5	4
(Heptachlor epoxide)	0.5	0.5
DDT-related compounds		
DDT	5	400
Chlorbenside[b]	20	1,000
Chlorobenzilate[b]	<50	2,564
DDD	10	a
Methoxychlor	100	4,000
Kelthane[b]	20-100	300
Perthane	500	100
Miscellaneous compounds		
BHC	10	a
Lindane	50	>15
Ovex[b]	25	200
Strobane	50	400
Sulfenone[b]	100	400
Tetradifon[b]	300	500
Toxaphene	10	400
Organophosphorus Insecticides		
Carbophenothion	5	0.8
Demeton	1	1
Diazinon	1	0.75
Guthion	5	5
Dioxathion	4	1
EPN	5-25	50
Ethion	3	1
Malathion	100-1,000	100
Phosdrin	0.8	1
Parathion	1	1

(continued)

APPENDIX A

TABLE 10 (Continued)

TOXICITY OF SELECTED PESTICIDES

(Dietary levels measured in ppm producing minimal or no effect after continuous feeding for 90 days to 2 years)

Pesticide	Toxicity	
	Rats	Dogs
Fungicides		
Captan	1,000	4,000
Dichlone (phygon)	1,580	500
Dyrene	5,000	>5,000
Dodine (cyprex)	200	>50
Folpet (phaltan)	3,200	10,000
Ferbam	250	200
Maneb	25	80
Thiram	100	200
Zineb	500	2,000
Ziram	250	200
Herbicides		
Chloro-IPC	2,000	2,000
Dalapon	300	2,000
Diuron	50-500	a
Fenuron	500	a
Monuron	250	1,000
2,4-D	300	400
Simazine	100	a
Trifluralin	2,000	1,000

[a] Data not available.

[b] Miticide.

APPENDIX A

TABLE 11

RECOVERY OF TOTAL ALDRIN/DIELDRIN AND HEPTACHLOR/HEPTACHLOR EPOXIDE RESIDUES[55]

(ppm)

Crop	Soil Treatment Per Acre			
	Aldrin/Dieldrin		Heptachlor/Heptachlor Epoxide	
	5 lb	25 lb	5 lb	25 lb
Radishes	0.09	0.52	0.13	0.59
Beets	0.07	0.25	0.08	0.42
Potatoes	0.14	1.20	0.14	1.22
Onions	0.00	0.05	traces	0.02
Carrots	0.24	1.26	0.55	3.98
Cucumbers	0.07	0.07	0.10	0.15
Lettuce	0.16	0.41	0.10	0.56
Beans (seeds)	0.00	0.00	0.00	0.00
Recovered from soil at harvest	1.57	11.08	2.38	11.41

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TABLE 12

THRESHOLD LIMIT VALUES FOR SELECTED PESTICIDES[76,98,99]

Pesticide	ppm	μg/m^3
Abate		15,000
Acrolein	0.1	250
Acrylamide-skin		300
Acrylonitrile-skin	20	45,000
Aldrin-skin		250
ANTU (alpha naphtyl thiourea)		300
Arsenic and compounds		500
Azinphos-methyl-skin		200
Cadmium oxide fume		100
Calcium arsenate		1,000
Camphor		2,000
Carbaryl (Sevin)		5,000
Carbon disulfide-skin	20	60,000
Carbon tetrachloride-skin	10	65,000
Chlordane-skin		500
Chlorinated camphene-skin		500
Chlorobenzene (monochlorobenzene)	75	350,000
o-Chlorobenzylidene malononitrile		
Chloropicrin	0.1	700
Chloroprene	25	90,000
Copper fume		100
Copper dusts and mists		1,000
Crag herbicide		15,000
Cyanide (as CN)-skin		5,000
Cyanogen	10	
2,4-D		10,000
DDT-skin		1,000
DDVP-skin		1,000
Demeton-skin		100
1,2-Dibromoethane (ethylene dibromide)-skin*	25	190,000
Dichloroethyl ether-skin	15	90,000
1,2-Dichloroethylene	200	790,000
Dieldrin-skin		250
Diethylamino ethanol-skin	10	50,000
Dimethyl 1,2-dibromo-2,2-dichloroethyl phosphate (Dibrom)		3,000
Dinitro-o-cresol-skin		200
Endrin-skin		100
Epichlorhydrin-skin	5	19,000
EPN-skin		500
Ferbam		15,000
Formaldehyde	5	6,000
Guthion		200

(continued)

APPENDIX A

TABLE 12 (Continued)

THRESHOLD LIMIT VALUES FOR SELECTED PESTICIDES

Pesticide	ppm	$\mu g/m^3$
Heptachlor-skin		500
Hexachloronaphthalene-skin		200
Hydrogen cyanide-skin	10	11,000
Lead arsenate		150
Lindane-skin		500
Malathion-skin		15,000
Mercury-skin		100
Mercury (organic compounds)-skin		10
Methoxychlor		15,000
Methyl bromide-skin	20	80,000
Methyl chloroform	350	1,900,000
Methyl isocyanate-skin	0.02	50
Napthalene	10	50,000
Nicotine-skin		500
Paraquat-skin*		500
Parathion-skin		100
Pentachlorophenol-skin		500
Phosdrin (Mevinphos)-skin		100
Phosphine	0.3	400
Phosphorous (yellow)		100
Pival (2-pivalyl-1,3-indandione)*		100
Pyrethrum		5,000
Ronnel*		15,000
Rotenone (commercial)		5,000
Sodium fluoroacetate (1080)-skin		50
Strychnine		150
Sulfur dioxide	5	13,000
2,4,5-T		10,000
TEDP-skin		200
TEPP-skin		50
Thallium (soluble compounds)-skin		100
Thiram		5,000
1,1,2-Trichloroethane-skin	10.	45,000
Triorthocresyl phosphate		100
Triphenyl phosphate		3,000
Turpentine	100	560,000
Warfarin		100

*Tentative result.

APPENDIX A

TABLE 13

AMBIENT AIR QUALITY STANDARDS[88]

Substance	Political Jurisdiction or Standard	Basic Standard		Permissible Standard	
		Concentration ($\mu g/m^3$ at STP)	Averaging Time	Concentration ($\mu g/m^3$ at STP)	Averaging Time
Acrolein	U.S.S.R.	100	24 hr	300	20 min
Acrolein	VDI 2306*	10	30 min	25	30 min
Arsenic (as As)	Czechoslovakia	3	24 hr		
Arsenic (as As)	U.S.S.R.	3	24 hr		
Carbon disulfide	Czechoslovakia	10	24 hr	30	30 min
Carbon disulfide	Ontario	450	30 min		
Carbon disulfide	Poland	15	30 min	45	30 min
Carbon disulfide	U.S.S.R.	10	24 hr	30	20 min
Chlorobenzene	VDI 2306*	5,000	30 min	15,000	30 min
Chlorobenzene	U.S.S.R.	100	24 hr	100	20 min
Chloroform	VDI 2306*	10,000	30 min	30,000	30 min
Chloroprene	U.S.S.R.	100	24 hr	100	20 min
Cresol	VDI 2306*	200	30 min	600	30 min
2-3 Dichloro-1-4 naphthaquinine	U.S.S.R.	50	24 hr	50	20 min
Epichlorohydrin	U.S.S.R.	200	24 hr	200	20 min
Formaldehyde	VDI 2306*	30	30 min	70	30 min
Formaldehyde	Czechoslovakia	15	24 hr	50	30 min
Formaldehyde	U.S.S.R.	12	24 hr	35	20 min
Malathion	U.S.S.R.			15	20 min
Methyl parathion	U.S.S.R.			8	20 min
Naphthalene	VDI 2306*	2,500	30 min	7,500	30 min

*For the Federal Republic of Germany, as determined and reported by Verein Deutscher Ingenieure-Kommission Reinhaltung der huft-Richtlinien, VDI-Verlag Gmbh., Dusseldorf.

APPENDIX A

TABLE 14

UNITED STATES PRODUCTION OF SELECTED PESTICIDES[44,69]
(Thousands of Pounds)

Pesticide	1939	1945	1950	1955	1960	1965	1966	1967
Calcium arsenate	41,349	25,644	45,348	3,770	6,590	4,192	2,890	2,500
Lead arsenate	59,569	70,522	39,434	14,776	10,062	7,098	7,328	6,000
White arsenic	44,686	48,698	26,546	a	a	a	a	a
Copper sulfate	134,032	251,000	174,600	156,176	116,000	47,272	41,504	33,992
Aldrin-toxaphene group[b]				77,025	90,671	118,832	130,470	120,183
BHC (Benzene hexachloride)[c]			76,698	56,051	37,444	a	a	a
DDT		33,243	78,150	129,693	164,180	140,785	141,349	103,411
Methyl bromide				9,222	12,659	14,303	16,345	19,665
Methyl parathion					11,794	29,111	35,862	33,344
Parathion				5,168	7,434	16,607	19,444	11,361
Nabam					2,978	2,489	2,053	1,361
2,4-D acid		917	14,156	34,516	36,185	63,320	68,182	77,139

[a] Data not available.

[b] Includes the chlorinated compounds, aldrin, dieldrin, endrin, chlordane, heptachlor, and toxaphene.

[c] Production of gamma isomer content in BHC was 17.1 million pounds in 1951, 10.7 million in 1955, and 6.9 million in 1960. Data in the table are on a gross basis.

TABLE 15

UNITED STATES SALES OF SYNTHETIC ORGANIC PESTICIDES BY TYPE OF USE, VOLUME, AND VALUE, 1964-67[68,69]

Type of Useage[a]	1964		1965		1966[b]		1967[c]	
	Amount	Percent-age of Total	Amount	Percent-age of Total	Amount	Percent-age of Total	Amount	Percent-age of Total
	Thousands of Pounds	Percent	Thousands of Pounds	Percent	Thousands of Pounds	Percent	Thousands of Pounds	Percent
Volume of sales:								
Fungicides	95,556	13.8	106,342	13.9	118,397	14.4	120,413	13.4
Herbicides and plant hormones	152,027	21.9	182,869	23.9	221,502	26.9	287,582	32.1
Insecticides, fumigants, rodenticides, and soil conditioners[d]	444,772	64.3	474,694	62.2	482,357	58.7	489,368	54.5
Total	692,355	100.0	763,905	100.0	822,256	100.0	897,363	100.0
	Thousands of Dollars	Percent	Thousands of Dollars	Percent	Thousands of Dollars	Percent	Thousands of Dollars	Percent
Value of sales:								
Fungicides	45,465	10.6	50,151	10.1	53,275	9.1	56,333	7.2
Herbicides and plant hormones	163,450	38.3	207,276	41.7	257,635	44.1	429,980	54.6
Insecticides, fumigants, rodenticides, and soil conditioners[d]	218,196	51.1	239,639	48.2	272,892	46.8	300,730	38.2
Total	427,111	100.0	497,066	100.0	583,802	100.0	787,043	100.0

[a] Classified by Tariff Commission according to the most important use; many chemicals actually have uses in more than one major category; the herbicides involve some repetition.

[b] Revised.

[c] Preliminary.

[d] A grouping required by the Tariff Commission to meet its need for separate data on cyclic chemicals; fumigants included may be fungicidal, nematocidal, and/or herbicidal, as well as insecticidal.

APPENDIX A

TABLE 16

UNITED STATES PRODUCTION OF PESTICIDAL CHEMICALS, 1964-67[69]
(Thousands of Pounds)

Chemical	1964	1965	1966	1967[a]
Fungicides				
Copper naphthenate	1,897	3,268	3,211	3,473
Copper sulfate[b]	41,186	47,272	41,504	33,992
Ferbam	1,838	2,384	1,379	2,331
Mercury fungicides	1,138	1,602	1,035	912
Nabam	2,251	2,489	2,053	1,361
Pentachlorophenol (PCP)[c]	36,901	39,965	43,262	44,239
2,4,5-Trichlorophenol and salts[d]	4,790	4,003	5,958	14,008
Zineb	6,664	5,075	4,721	3,055
Other organic fungicides	48,352	44,969	63,818	63,269
Total[e]	145,647	151,027	166,941	166,640
Herbicides				
2,4-D acid[f]	(53,714)	(63,320)	(68,182)	(77,139)
2,4-D acid esters and salts	54,366	63,360	72,522	83,750
Disodium methyl arsenate	2,167			
DNBP	4,146	4,619	g	g
DNBP, ammonium salt	55	59	85	58
Phenyl mercuric acetate (PMA)[h]	495	588	502	518
Sodium chlorate[i]	35,000	32,000	32,000	30,000
2,4,5-T acid[f]	(11,434)	(11,601)	(15,489)	(14,552)
2,4,5-T acid esters and salts	12,963	13,516	18,059	27,189
Other organic herbicides	87,046	105,861	148,765	206,759
Total	196,238	220,003	271,933	348,274
Insecticides, Fumigants, Rodenticides [j]				
Aldrin-toxaphene group[k]	105,296	118,832	130,470	120,183
Calcium arsenate	6,958	4,192	2,890	2,500[l]
DDT	123,709	140,785	141,349	103,411
Dibromochloropropane	5,314	3,433	8,722	5,240
Lead arsenate	9,258	7,098	7,328	6,000[l]
Methyl bromide[m]	16,994	14,303	16,345	19,665
Methyl parathion	18,640	29,111	35,862	33,344
Parathion	12,768	16,607	19,444	11,361
TEPP	669			
Other organics	163,715	167,398	199,404	202,600
Total	463,321	501,729	561,596	504,304
Grand Total	805,206	872,759	1000,688	1019,218

For footnotes, see next page.

Footnotes for Table 16

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[a] Preliminary.

[b] Shipments by producers to agriculture (including for use as minor plant nutrient.

[c] Not only a wood preservative for wood rot control but a herbicide and desiccant.

[d] Requirement as a 2,4,5-T intermediate is subtracted from figures.

[e] Sulfur not included may amount to 150 million pounds.

[f] Figures in parentheses, because of duplication, are not included in totals.

[g] Separate figure not available.

[h] Also a fungicide.

[i] Estimated shipments to producers of herbicides and defoliants.

[j] Includes a small quantity of synthetic soil conditioners; does not include the fumigants, carbon tetrachloride, carbon disulfide, ethylene dibromide and ethylene dichloride, which have many other uses; nor does it include paradichlorobenzene (classed by Tariff as an intermediate) or inorganic rodenticides.

[k] Includes aldrin, chlordane, dieldrin, endrin, heptachlor, Strobane, and toxaphene.

[l] Estimated.

[m] Fumigant for control of both insects and weeds.

TABLE 17

UNITED STATES PRODUCTION AND SALES OF SYNTHETIC ORGANIC PESTICIDES,[a] 1962-67[69]

Calendar Year	Quantity (thousands of pounds)	Increase over Previous Year (percent)	Value (thousands of dollars)	Increase over Previous Year (percent)
		Production		
1962	729,718	4.3	427,373[b]	18.1
1963	763,477	4.6	456,068[b]	6.7
1964	782,749	2.5	481,955[b]	5.7
1965	877,197	12.1	582,899[b]	20.9
1966[c]	1,013,110	15.5	727,772[b]	24.9
1967[d]	1,049,663	3.6	914,018[b]	25.6
		Sales (Domestic and Export)		
1962	633,962	3.6	346,301	14.3
1963	651,471	2.8	369,140	6 6
1964	692,355	6.3	427,111	15.7
1965	763,905	10.3	497,066	16.4
1966[c]	822,256	7.6	583,802	17.4
1967[d]	897,363	9.1	787,043	34.8

[a] Includes a small quantity of soil conditioners.

[b] Calculated from production and unit sales value, manufacturers' level.

[c] Revised.

[d] Preliminary.

TABLE 18

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES[30]

Pesticide	Manufacturer	Plant Site
DDT	Allied Chemical Corp.	Marcus Hook, Pa.
	Diamond Alkali Co.	Green Bayou, Tex.
	Geigy Chemical Corp.	McIntosh, Ala.
	Lebon Chemical Corp.	Lebanon, Pa.
	Montrose Chemical Corp. of Calif.	Torrance, Calif.
	Olin Mathieson Chemical Corp.	Huntsville, Ala.
2,4-D	Chemical Insecticide Corp.	Metuchen, N.J.
	Chipman Chemical Co., Inc.	Portland, Oreg.; Kansas City, Mo.; St. Paul, Minn.
	Diamond Alkali Co.	Newark, N.J.
	Dow Chemical Co.	Midland, Mich.
	Monsanto Co.	Monsanto Ill.; Nitro, W.Va.
	Thompson Chemicals Corp.	St. Louis, Mo.
BHC and lindane	Diamond Alkali Co.	Green Bayou, Tex.
	Hooker Chemical Corp.	Niagara Falls, N.Y.
	Pittsburgh Plate Glass Co.	Natorium, W.Va.

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Alabama		12
	Etowah	
	Houston	
	Jefferson	
	Mobile	
	Montgomery	3
	Morgan	
	Pike	
	Talladega	2
	Washington	

(continued)

TABLE 18 (Continued)

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Arizona		11
	Maricopa	8
	Pinal	2
	Yuma	
Arkansas		5
	Jefferson	2
	Phillips	
	Pulaski	2
California		56
	Alameda	
	Contra Costa	4
	Fresno	5
	Imperial	5
	Kern	2
	Los Angeles	16
	Marin	
	Monterey	2
	Orange	2
	Riverside	3
	San Francisco	
	San Joaquin	3
	San Mateo	
	Santa Barbara	
	Santa Clara	2
	Santa Cruz	
	Stanislaus	
	Tulare	2
	Ventura	2
	Yolo	
Colorado		7
	Adams	2
	El Paso	
	Pueblo	
	Weld	3

(continued)

TABLE 18 (Continued)

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Connecticut		1
	Fairfield	
Florida		18
	Broward	
	Dade	2
	Duval	2
	Hillsborough	3
	Lake	
	Manatee	
	Orange	4
	Pasco	
	Pinellas	2
	Polk	
Georgia		18
	Bibb	
	Burke	
	Chatham	
	Cobb	
	Coffee	
	Crisp	
	Dougherty	2
	Fulton	5
	Lowndes	
	Peach	
	Polk	
	Terrell	
	Tift	
Idaho		1
	Canyon	
Illinois		15
	Cook	11
	Du Page	
	Effingham	
	McHenry	
	Stark	

(continued)

TABLE 18 (Continued

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Indiana		1
	Henry	
Iowa		7
	Hardin	
	Page	2
	Polk	3
	Woodbury	
Kansas		4
	Reno	
	Wyandotte	3
Kentucky		1
	Fayette	
Louisiana		7
	Bossier	
	Caddo	
	Orleans	2
	Quachita	
	St. Landry	
	Terrebonne	
Maryland		3
	Baltimore City	
	Washington	
	Wicomico	
Massachusetts		7
	Middlesex	5
	Norfolk	2
Michigan		7
	Allegan	
	Clinton	
	Kent	
	Lenawee	
	Midland	
	Muskegon	
	Van Buren	

(continued)

TABLE 18 (Continued)

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Minnesota		5
	Dakota	
	Hennepin	
	Ramsey	2
	Winona	
Mississippi		9
	Bolivar	
	Coahoma	
	Madison	
	Monroe	
	Quitman	
	Sunflower	
	Washington	3
Missouri		9
	Buchanan	2
	Clay	
	Jackson	
	St. Louis	2
	St. Louis City	3
Nebraska		4
	Douglas	4
Nevada		1
	Lincoln	
New Jersey		15
	Burlington	
	Cumberland	2
	Essex	3
	Gloucester	
	Hudson	
	Middlesex	2
	Ocean	
	Passaic	
	Salem	
	Somerset	2

(continued)

TABLE 18 (Continued)

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	Plant Sites*
New York		12
	Albany	
	Bronx	
	Dutchess	
	Kings	
	Niagara	
	Oneida	2
	Onondaga	
	Orleans	
	Putnam	
	St. Lawrence	
	Yates	
North Carolina		16
	Avery	
	Bladen	
	Cumberland	
	Forsyth	
	Hertford	
	Johnston	2
	Lenoir	
	Moore	2
	Northampton	2
	Pitt	
	Wayne	
	Wilson	2
Ohio		10
	Allen	
	Erie	
	Franklin	2
	Fulton	
	Jefferson	
	Lucas	
	Scioto	2
	Stark	

(continued)

TABLE 18 (Continued)

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Oklahoma		3
	Choctaw	
	Garfield	
	Tulsa	
Oregon		4
	Clackamas	
	Multnomah	3
Pennsylvania		8
	Berks	
	Lancaster	
	Lebanon	
	Montgomery	2
	Philadelphia City	3
South Carolina		5
	Allendale	
	Hamptom	
	Lexington	
	Spartanburg	
	Williamsburg	
Tennessee		3
	Franklin	
	Shelby	2
Texas		34
	Angelina	
	Bexar	2
	Brazos	
	Burleson	
	Cameron	3
	Dallas	2
	Deaf Smith	
	Ector	
	Ellis	
	El Paso	

(continued)

TABLE 18 (Continued)

LOCATIONS AND NUMBER OF MANUFACTURERS OF PESTICIDES

AGRICULTURAL CHEMICALS
(Pesticides)

State	County	No. of Plant Sites*
Texas (continued)		
	Fannin	
	Hale	
	Harris	6
	Hidalgo	5
	Hunt	
	Liberty	
	Lubbock	2
	McLennan	
	Reeves	
	Terry	
Virginia		5
	Alexandria	
	Botetourt	
	Lunenburg	
	Norfolk City	
	Roanoke City	
Washington		8
	Chelan	
	King	
	Pierce	
	Yakima	5
West Virginia		1
	Jefferson	
Wisconsin		7
	Dane	
	Dodge	
	Milwaukee	4
	Rock	
UNITED STATES		340

*Those counties where no number is indicated have one plant.

APPENDIX A

TABLE 19

TOTAL QUANTITIES OF PESTICIDES USED BY FARMERS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964[71]

Type of Pesticide Product[a]	Pounds of Active Ingredients (in thousands)			
	Total	Crops[b]	Livestock[c]	Other[d]
Fungicides				
Sulfur	136,823	135,228	404	1,191
Other inorganic	9,327	9,264	47	16
Total inorganic	146,150	144,492	451	1,207
Organic	23,929	21,451	2,373	105
Total fungicides	170,079	165,943	2,824	1,312
Herbicides				
Inorganic	10,434	9,565		869
Organic	73,604	66,749		6,855
Total herbicides	84,038	76,314		7,724
Insecticides				
Inorganic	7,651	7,095	15	541
Botanicals and biologicals	336	249	86	1
Synthetic organic	147,849	135,744	10,390	1,715
Other organic	160	96	63	1
Total insecticides	155,996	143,184	10,554	2,258

(continued)

TABLE 19 (Continued)

TOTAL QUANTITIES OF PESTICIDES USED BY FARMERS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964

Type of Pesticide Product[a]	Pounds of Active Ingredients (in thousands)			
	Total	Crops[b]	Livestock[c]	Other[d]
Miscellaneous pesticides[e]				
Miticides	3,093	3,059	10	24
Fumigants	24,867	23,665		1,202
Defoliants and desiccants	16,129	11,906		4,223
Rodenticides	76			76
Growth Regulators	2,566	2,566		
Repellents	656		656	
Total miscellaneous pesticides	47,387	41,196	666	5,525
Total pesticide products (not including petroleum)	457,500	426,637	14,044	16,819
Petroleum[f]	313,411	232,561	18,855	61,995
Total (including petroleum)	770,911	659,198	32,899	78,814

[a] All technical pesticide materials classified by anticipated major use. Each ingredient included in only one category.

[b] Includes all crops, pasture, rangeland, and land in summer fallow.

[c] Includes livestock buildings.

[d] Includes pesticides for all other noncrop and nonlivestock uses except for treating seeds, stored crops, or storage buildings.

[e] The enumeration may have been incomplete for some miscellaneous pesticides.

[f] Used primarily in insecticidal and herbicidal preparations.

APPENDIX A

TABLE 20

COMPARISON OF FARM USE OF SELECTED PESTICIDE CHEMICALS WITH PRODUCTION, UNITED STATES, 1964[71]

	Active Ingredients	
Type of Pesticide Product	U.S. Production (Thousands of Pounds)	Percentage Used by Farmers in 48 States[a] (percent)
Fungicides[b]	108,746	30.2
Herbicides:		
2,4-D[c]	54,366	63.4
2,4,5-T[c]	12,963	12.8
Other herbicides[d]	128,909	51.7
Total herbicides	196,238	52.3
Insecticides, fumigants, rodenticides, and miticides:		
Chlorinated hydrocarbons:		
Aldrin-toxaphene[e]	105,296	52.2
DDT	123,709	27.1
Organic phosphorous compounds:		
Parathion	12,768	50.3
Methyl parathion	18,640	53.6
TEPP	669	23.9
Other	202,239	38.5
All insecticides, fumigants, rodenticides, and miticides	463,321	39.9
Total pesticides[f]	768,305	42.4

[a] Does not include sulfur, pentachlorophenol, or petroleum. Includes all other pesticides used by farmers, except those used in the treatment of seeds, stored crops, or storage buildings.

[b] Does not include sulfur or pentachlorophenol.

[c] Acids, esters, and salts.

[d] Includes plant hormones, defoliants, and desiccants.

[e] Includes aldrin, chlordane, dieldrin, endrin, heptachlor, and toxaphene.

[f] Does not include sulfur, pentachlorophenol, or petroleum.

APPENDIX A

TABLE 21

UNITED STATES ACREAGES TREATED ANNUALLY WITH INSECTICIDES (EXCLUDING HAWAII AND ALASKA), 1962[44]

Land Use	Acres in Category (in millions)	Acreage on Which Insecticides Applied (in millions)	Percentage of Category Treated
Forest lands	640	1.8	0.28
Grassland pasture	630	1.6	0.25
Desert, swamps, dunes, and wildland	77	2.5	3.24
Water areas	32.6	0	
Cropland and cropland pasture	457	68.6	15.0
Land devoted to			
Fruits, nuts	2.8	2.3	80
Cotton	15.8	11.9	75
Vegetables	4.1	2.1	50
Grains	216.6	32.5	15
All other crops, etc.	217.6	19.9	9
Urban or built-up areas	53	15	28.3
Nonforested parks, wildlife refuges, duck reserves, national defense sites	43		
Total U.S. acreage (48 States)	1,934.6	89.5	4.6

APPENDIX A

TABLE 22

QUANTITIES OF SELECTED TYPES OF INSECTICIDE INGREDIENTS USED ON CROPS, BY REGIONS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964[71]

Type of Insecticide Product	Pounds of Active Ingredients (in thousands)										
	North-east	Lake States	Corn Belt	North-ern Plains	Appa-lachian	South-east	Delta States	South-ern Plains	Moun-tain	Pacific	48 States
Inorganic insecticides	1,714	688	291		1,300	175		2,516		411	7,095
Synthetic organic insecticides											
Chlorinated hydrocarbons											
DDT	1,001	511	612	12	2,780	12,540	6,851	4,715	773	2,040	31,835
TDE	128	104	123		1,040	1,604	126	25	91	134	3,375
BHC and lindane	22	24	7	1	182	471	9	118	3	118	955
Aldrin	*	761	8,581	491	1,066	189	*			24	11,119
Dieldrin	158	69	126	51	46	209	*	73	175	17	927
Endrin	13	12	*	*	155	484	893	231	42	318	2,151
Heptachlor	17	105	974	46	116	2	8		33		1,301
Toxaphene	3	53	1,298	1	4,179	11,502	10,256	5,065	1,040	792	34,189
Other	236	53	68	9	77	481	824	1,695	13	527	3,983
Total chlorinated hydrocarbons	1,583	1,692	11,790	613	9,641	27,482	18,972	11,922	2,170	3,970	89,835
Phosphorus compounds											
Parathion	366	95	110	646	246	1,071	34	1,420	516	1,634	6,138
Methyl parathion	*		7	3	78	1,970	5,326	2,558	28	*	9,981
Malathion	265	43	38	5	280	82	228	317	424	2,384	4,066
Diazinon	30	13	886	650	361	13			99	225	2,277
Demeton	10	*		3	33	4	*	12		200	269
Disulfoton	2	170	*	8	138	67	22	313	34	*	890
Azinphosmethyl	455	212	139		95	338	12	6	63	925	2,245
Phorate	62		316	762	104	9	9		*		1,263
Other	121	16	81	34	192	705	210	725	324	956	3,364
Total phosphorus compounds	1,313	555	1,709	2,111	1,527	4,259	5,842	5,351	1,489	6,337	30,492

(continued)

APPENDIX A

TABLE 22 (Continued)

QUANTITIES OF SELECTED TYPES OF INSECTICIDE INGREDIENTS USED ON CROPS, BY REGIONS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964

Type of Insecticide Product	Pounds of Active Ingredients (in thousands)										
	North-east	Lake States	Corn Belt	North-ern Plains	Appa-lachian	South-east	Delta States	South-ern Plains	Moun-tain	Pacific	48 States
Other synthetic organics											
Carbaryl	2,316	841	514	25	1,283	2,789	2,229	2,321	267	2,239	14,824
Other	18	*	33		10	307	18	6	3	194	592
Total other synthetic organics	2,334	844	547	25	1,293	3,096	2,247	2,327	270	2,433	15,416
Total synthetic organics	5,230	3,091	14,046	2,749	12,461	34,837	27,061	19,600	3,929	12,740	135,744
Other organics	4		21	5	15	24	7	10	1	258	345
Total insecticides	6,948	3,779	14,358	2,754	13,776	35,036	27,068	22,126	3,930	13,409	143,184

*Less than 10,000 acres treated.

APPENDIX A

TABLE 23

QUANTITIES OF SELECTED HERBICIDES USED ON CROPS, BY REGIONS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964[71]

Type of Herbicide Product	Pounds of Active Ingredients (in thousands)										
	North-east	Lake States	Corn Belt	North-ern Plains	Appa-lachian	South-east	Delta States	South-ern Plains	Moun-tain	Pacific	48 States
Inorganic herbicides[a]	2,296	b	234	122	1,321	451	791	464	3,577	262	9,565
Organic herbicides											
Arsenicals[a]			b		7	11	765	214			1,006
Phenoxy											
2,4-D[a]	1,097	2,552	6,181	6,829	881	522	699	1,777	4,545	4,604	29,687
2,4,5-T	8	8	80	123	52	16	258	400	22	12	979
MCPA	48	377	119	612	101	9		23	44	121	1,454
Other phenoxy	12	22	64	14	28	472	4		b	67	684
Total phenoxy	1,165	2,959	6,444	7,578	1,062	1,019	961	2,200	4,612	4,804	32,804
Phenyl urea											
Monuron	122	15			14		27	43	b	b	231
Diuron	18	b	23	b	102	174	673	39	b	84	1,119
Other phenyl urea	49	43	164	b	28	14	12		b	65	379
Total phenyl urea	189	60	187	2	144	188	712	82	6	159	1,729
Carbamates											
Propanil							949	2,903			3,852
IPC and CIPC	b		169	b	113	110	14		b	384	795
EPTC, molinate, and vernolate	b	162	65	71	28	90	b		106	103	633
CDAA (Randox)	b	296	3,222	105			13		b		3,662
Other carbamates		1	b	9		10			46	60	130
Total carbamates	7	459	3,460	188	141	210	979	2,903	178	547	9,072
Dinitro group	1,595	55	61		210	726			14	535	3,196

(continued)

TABLE 23 (Continued)

QUANTITIES OF SELECTED HERBICIDES USED ON CROPS, BY REGIONS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964

Type of Herbicide Product	Pounds of Active Ingredients (in thousands)										
	North-east	Lake States	Corn Belt	North-ern Plains	Appa-lachian	South-east	Delta States	South-ern Plains	Moun-tain	Pacific	48 States
Triazine group											
Atrazine	1,584	3,524	3,304	804	1,343	138	40	30	b	68	10,837
Simazine	53	35	16	b	2		b		b	55	190
Other triazines								92			92
Total triazines	1,637	3,559	3,320	810	1,345	138	44	122	21	123	11,119
Chlorinated aliphatic	731	538	143	254	b	b	203	25	b	13	1,912
Benzoic group	b	295	2,096	197	b	14	54	b	28	515	3,214
Trifluralin and benefin			176		140	176	190	30		23	735
Other organics	35	169	865	14	298	261	138	81	41	60	1,962
Total organic herbicides	5,362	8,094	16,761	9,043	3,352	2,744	4,046	5,667	4,901	6,779	66,749
Total herbicides	7,658	8,141	16,995	9,165	4,673	3,195	4,837	6,131	8,478	7,041	76,314

[a] May include quantities used for purposes other than as herbicides.
[b] Less than 10,000 acres treated.

TABLE 24

QUANTITIES OF SELECTED FUNGICIDES USED ON CROPS BY REGIONS IN 48 CONTIGUOUS STATES OF THE UNITED STATES, 1964[71]

Type of Fungicide Product	Pounds of Active Ingredients (in thousands)										
	North-east	Lake States	Corn Belt	North-ern Plains	Appa-lachian	South-east	Delta States	South-ern Plains	Moun-tain	Pacific	48 States
Inorganic fungicides											
Sulfur[a]	1,520	2,182	4,462	105	15,137	64,536	b	5,823	1,031	40,408	135,228
Other inorganics											
Copper sulfates[a]	111	b	776		152	1,142				1,672	3,868
Other coppers[a]	68	b	176		263	2,116		14		137	2,788
Zinc salts[a]	115	12	28			971		12		156	1,294
Other inorganic	14	5	40		b	1,245		b	b	4	1,314
Total inorganic	1,828	2,228	5,482	105	15,553	70,010	24	5,851	1,034	42,377	144,492
Organic fungicides											
Dithiocarbamates	3,241	1,275	1,670	204	2,437	2,796	129	74	158	814	12,798
Phthalimides	1,507	536	612	b	2,292	53	66	3	43	713	5,825
Imidazolines	87	b	b							10	103
Quinones	741	83	119		b	b				87	1,031
Pentachlorophenol[a]	14		242				6			b	274
Karathane[a]	4		b		48	b			b	17	77
Other organics	616	208	48		287	6		97		81	1,343
Total organic fungicides	6,210	2,104	2,699	204	5,065	2,855	201	174	205	1,734	21,451
Total fungicides	8,038	4,332	8,181	309	20,618	72,865	225	6,025	1,239	44,111	165,943

[a] May include quantities used for purposes other than as fungicides.

[b] Less than 10,000 acres treated.

APPENDIX A

TABLE 25

AVERAGE CONCENTRATIONS OF APPARENT ORGANOCHLORINE INSECTICIDES FOUND IN RAINWATER SAMPLES (Expressed As Parts Per 10^{12} Parts of Rainwater)[107]

Samples	Gamma-BHC	Dieldrin	p,p'-DDT
Monthly samples			
Apr.-Oct. 1964	97(77-120)[a]	28(19-36)	
Nov. 1964-Feb. 1965	100(32-164)	20(10-25)	3(1-4)
Supplementary samples			
Jan. and Mar. 1965	29(12-52)[b]	9(3-16)[b]	3(2-4)[c]
Reagent blanks	2(1-3)	3(1-4)	<0.5

[a] Ranges of concentrations are shown in parentheses.

[b] Five samples.

[c] Four samples.

APPENDIX A

TABLE 26

ORGANOCHLORINE PESTICIDE RESIDUE LEVELS IN LONDON RAINWATER, 1965[2]

	Residue Concentration Parts Per Million-Million						
Month	alpha BHC	beta BHC	gamma BHC	HEOD (dieldrin)	p,p' -DDE	p,p' -TDE	p,p' -DDT
Station 1							
Feb.	40	90	90	50	70		400
Mar.	15		60	60	20		115
Apr.	30		80	50			300
May	20	65	70	95			190
June	30		55	25		15	70
July	25		40	10	15	85	85
Station 2							
Mar.	10		20	20			
Apr.	20		70	70		100	140
May	20	25	55	50			220
June	20		155	20		50	125
July	30		70	15	10	20	80

APPENDIX A

TABLE 27

PESTICIDE CONTENT OF DUST SAMPLE, CINCINNATI, 1965[19]

Pesticide	Concentration (ppm)*
DDT (Tech. grude)	0.6
Chlordane	0.5
DDE	0.2
Ronnel	0.2
Heptachlor epoxide	0.04
2,4,5-T	0.04
Dieldrin	0.003
Total Organic chlorine	1.34
Total Organic sulfur	0.5

*Based on air-dried weight of dust.

APPENDIX A

TABLE 28

ATMOSPHERIC CONCENTRATION OF MALATHION, 1955 PLANADA, CALIF., STUDY[17]

Time	Location Unprotected Area (μg/m³)	 Semisheltered Area (μg/m³)
During spraying		
Range	61-75	50-125
Average	67	88
One hour after spraying	44*	34*
Overall sample		
Range	50-84	51-60
Average	67	56

*One sample.

TABLE 29

ATMOSPHERIC PESTICIDE LEVELS[95]

Atmospheric Pesticide Levels in Agricultural Communities, 1963
(Concentrations in $\mu g/m^3$)

Community		Period						
		5/23-5/30	5/31-6/3	6/18-6/19	6/20-6/22	6/23-6/24	7/4-7/7	7/8-7/11
Edinburg, Tex.	No. samples*	0.005	0.004	0.002	0.002	0.002		
	DDT	0.003	0.003	0.003	0.010	0.007		
Weslaco, Tex.	No. samples*	0.005	0.004	0.002	0.003	0.002		
	DDT	0.002	<0.001	0.023	0.023	0.007		
Harlingen, Tex.	No. samples*						0.004	0.003
	DDT						<0.001	<0.0001

*Composites of samples were analyzed.

Atmospheric Pesticide Levels in Agricultural Communities, 1964
(Ranges of Concentrations in $\mu g/m^3$)

	No. samples analyzed	DDT	Chlordane	Aldrin	Toxaphene
Florida City, Fla.	6	0.0002-0.002	<	<0.003-0.001	<
Fort Valley, Ga.					
May-June	6	<0.001 -0.007[a]	2-6	<	<
Sept.	10	<0.001 -0.004	<	<	<
Inman, S.C.	8	<0.002 -0.0012	0.0005-0.0056	<	<
Lake Alfred, Fla.	6	<	0.0006-0.0013	<	<
Leland, Miss.	6	0.0005-0.02	<0.002 -0.002	<	<
Newellton, La.	5	0.0005-0.007	<0.002 -0.0015	<	<0.002-0.015

(continued)

<=Below detectable level.

()=Number of samples having less than detectable level.

[a] Values ranged from less than minimum detectable to the highest value, 7.

TABLE 29 (Continued)

ATMOSPHERIC PESTICIDE LEVELS

Atmospheric Pesticide Levels in Communities with Pest Control Programs, 1964
(Ranges of Concentrations in μg/m³)

		Community A		Community B	
	Houston	During Fogging	After Fogging	During Fogging	After Fogging
No. samples	3	4	3	6	6
DDT	<0.002 -0.0004	<	<	0.1 -8	0.002-0.011
Malathion	0.0001-0.0002	0.008-0.022	0.001-0.002	<0.001-0.08	<

<=Below minimum detectable level.

( )=Number of samples having less than detectable level.

Atmospheric Pesticide Levels in a Large Eastern City with a Pest Control Program
(Community C), 1964
(Concentrations in μg/m³)

		First Week[a]	Second Week[b]	Third Week[c]
	Neighborhood	4 Samples	4 Samples	3 Samples
DDT	a	<	<	0.1 -0.43
	b	<	0.23-0.3	0.003
Malathion	a	0.006-0.025	<	0.006-0.14
	b	<-0.016	<	0.0005

(continued)

<=Below detectable level.

[a] Only malathion used in fogging.

[b] Only DDT used in fogging.

[c] Both DDT and malathion used in fogging.

TABLE 29 (Continued)

ATMOSPHERIC PESTICIDE LEVELS

Calculated Possible Daily Respiratory Intake of DDT

Agricultural Community	μg DDT/ 24 hr	Pest Control Community	μg DDT/ 24 hr
Fort Valley, Ga.	0.2	Community C	2.6
Leland, Miss.	0.5	Community B	32
Weslaco, Tex.	0.8		

APPENDIX A

TABLE 30

DDT AND ETHION LEVELS IN THE AIR BEFORE AND AFTER APPLICATION[46]

Time	Concentration ($\mu g/m^3$) DDT	Concentration ($\mu g/m^3$) Ethion
7 days prior to application	<35.3*	<35.3*
12 hours after application	10,600	3,800
7 days after application	1,765	353
14 days after application	70.6	<35.3*
21 days after application	<35.3*	<35.3*
30 days after application	<35.3*	<35.3*

*Less than sensitivity of detection.

APPENDIX A

TABLE 31

PHENOXY HERBICIDES IN THE AIR AT TWO WASHINGTON SITES, 1964[8]

	2,4-D Esters				
Collector	Methyl	Isopropyl	Butyl	Isooctyl	2,4,5-T Methyl Ester
PULLMAN					
Number of Days Found (out of 99)					
Impactor[a]	3	29	13		9
Impinger[b,c]	5	1			
Average Concentration of Ester Found, μg/m³					
Impactor	0.006	0.116	0.059		0.045
Impinger	0.031	0.007			
Maximum Concentration of Ester Found, μg/m³					
Impactor	0.34	1.96	1.04		3.38
Impinger	1.00	0.69			
KENNEWICK					
Number of Days Found (out of 102)					
Impactor	5	39	22	1	14
Impinger	4	15	5		7
Average Concentration of Ester Found, μg/m³					
Impactor	0.017	0.073	0.079	0.005	0.012
Impinger	0.055	0.078	0.028		0.013
Maximum Concentration of Ester Found, μg/m³					
Impactor	0.47	0.72	0.82	0.53	0.63
Impinger	5.12	1.30	1.27		0.78

[a] Aerosol sample.

[b] Gaseous sample.

[c] Data on methyl esters include the sum of all salts and amines which were converted to the methyl ester for analysis.

APPENDIX A

TABLE 32

CONCENTRATIONS OF p,p'-DDT ASSOCIATED WITH SUSPENDED PARTICULATE MATTER IN PITTSBURGH AIR IN 1964[7] ($\mu g/m^3$)

Sample Period	Particulate	
	Respirable	Nonrespirable
6/22- 7/6	0.00	0.10
7/6 - 7/20	1.14	1.22
7/20- 8/3	0.23	<*
8/4 - 8/18	0.06	<*
8/31- 9/14	<*	<*
9/15- 9/29	0.13	<*
10/2 -10/16	.10	<*
10/19-11/2	<*	<*
11/3 -11/17	<*	<*
11/18-12/2	0.11	<*

* < Indicates less than a detectable amount.

APPENDIX A

TABLE 33

ORGANOCHLORINE PESTICIDES FOUND IN LONDON AIR[2]

	Concentration* Found by Gas-Liquid Chromatography	
Compound	Silicone E. 301	Apiezon L
Alpha-BHC	1	1
Gamma-BHC	5	11
Dieldrin (HEOD)	18	21
p,p'-DDE	4	7
p,p'-DDT	3	3
p,p'-TDE	3	3

*Grams per 10^{12} gram or $\mu g/10^6 g$.

APPENDIX A

TABLE 34

MAXIMUM PESTICIDE LEVELS FOUND IN AIR SAMPLES[64]
(Levels in μg/m)

Pesticides	Baltimore (123 Samples)	Buffalo (57 Samples)	Dothan (90 Samples)	Fresno (120 Samples)	Iowa City (94 Samples)	Orlando (99 Samples)	Riverside (94 Samples)	Salt Lake City (100 Samples)	Stoneville (98 Samples)
p,p'-DDT	0.0195 (89)*	0.011 (40)	0.177 (88)	0.0112 (62)	0.0027 (56)	1.56 (99)	0.0244 (85)	0.0086 (62)	0.95 (98)
o,p'-DDT	0.003 (59)	0.0029 (24)	0.088 (72)	0.0055 (28)	0.0021 (21)	.5 (95)	0.0062 (44)	0.0014 (29)	0.25 (98)
p,p'-DDE	0.0024 (4)		0.0132 (32)	0.0064 (3)	0.0037 (10)	.131 (29)	0.0113 (6)		0.047 (76)
o,p'-DDE			0.0039 (13)			0.0096 (7)			0.0019 (25)
alpha-BHC	0.0045 (27)			0.0045 (4)	0.0044 (9)			0.0099 (30)	
Lindane	0.0026 (4)				0.0001 (1)			0.007 (24)	
beta-BHC	0.0022 (4)							0.0018 (3)	
delta-BHC								0.0099 (5)	
Heptachlor					0.0192 (37)	0.0023 (7)			
Aldrin					0.0080 (1)				
Toxaphene			0.068 (11)			2.520 (9)			1.340 (55)
2,4-D								0.0040 (1)	
Dieldrin						0.0297 (50)			

(continued)

TABLE 34 (Continued)

MAXIMUM PESTICIDE LEVELS FOUND IN AIR SAMPLES
(Levels in μg/m)

Pesticides	Baltimore (123 Samples)	Buffalo (57 Samples)	Dothan (90 Samples	Fresno (120 Samples)	Iowa City (94 Samples)	Orlando (99 Samples	Riverside (94 Samples)	Salt Lake City (100 Samples)	Stoneville (98 Samples)
Endrin									0.0585 (25)
Parathion						0.465 (37)			
Methyl parathion			0.0296 (9)			0.0054 (3)			0.129 (40)
Malathion						0.0020 (4)			
DEF									0.016 (12)

*Value in parenthesis indicates the number of samples containing detectable amounts of the pesticide (about 0.001 g/m).

APPENDIX A

TABLE 35

HORIZONTAL TRANSPORT OF PARTICLES IN LIGHT WINDS[6]

Drop Diameter (μ)	Particle Type	Distance Traveled in 3 mph Wind While Falling 10 ft
400	Coarse aircraft spray	8.5 ft
150	Medium aircraft spray	22 ft
100	Fine aircraft spray	48 ft
50	Air carrier sprayers	178 ft
20	Fine spray and dusts	0.21 mile
10	Usual dusts and aerosols	0.84 mile
2	Aerosols	21 miles

TABLE 36

HORIZONTAL DRIFT OF SPRAYED PARTICLES[76]

Drift of Particles When Sprayed from 5-ft Height

Particle Diameter (μ)	Crosswind Speed		
	1 mph	5 mph	10 mph
100	7 ft, 6 inches	37 ft, 6 inches	75 ft
300	9 inches	4 ft, 3 inches	8 ft, 4 inches
600	3 inches	1 ft, 1 inch	2 ft, 1 inch
800	2 inches	6 inches	1 ft, 3 inches
Drift of Particles When Sprayed from 50-ft Height			
100	75 ft	375 ft	750 ft
300	8 ft, 4 inches	42 ft	83 ft
600	2 ft, 1 inch	10 ft, 5 inches	20 ft, 8 inches
800	1 ft, 3 inches	5 ft, 9 inches	12 ft

TABLE 37

DEATHS FROM SOME INSECT-BORNE DISEASES, UNITED STATES[44]

Year	Malaria	Rocky Mountain Spotted Fever	Tularemia	Arthropod-Borne Encephalitis
1940	1,442	83	189	[a]
1945	443	128	122	[a]
1950	76	31	15	65[b]
1955	18	8	9	32
1960	7	11	4	[a]

[a] Not separately available.

[b] Data for 1952.

TABLE 38

REPORTED CASES OF SELECTED NOTIFIABLE DISEASES, UNITED STATES[111]

Year	Dengue	Malaria	Rocky Mountain Spotted Fever	Tularemia	Murine Typhus
1930	203	98,491	197	661	511
1935	582	137,513	492	782	1,287
1940	66	78,129	457	1,620	1,878
1945	106	62,763	472	900	5,193
1950	26	2,184	464	927	685
1955		522	295	584	135
1960		72	204	390	68
1961		73	219	365	46

TABLE 39

EFFECTS OF INSECTICIDE USE ON CROP YIELDS[44]

COTTON CROPS

Location	Years	Percent Increase in Yields All Years	Pre-1945	Since 1945
Florence, S.C.	1928-58	40.6	23.6	53.9
Tallulah, La.	1920-56	31.2	26.4	41.3
Waco, Tex.	1939-58	41.8	34.0	53.0

SMALL GRAIN CROPS

Crop	Year	Location	Yield (lb/acre) Untreated	Treated	Percent Increase after Treatment with Parathion
Wheat	1951	Oklahoma	54	666	1,133
	1952	Oklahoma	762	1,242	63
	1952	Oklahoma	546	1,398	156
	1956	Texas	804	1,254	56
	1956	Texas	1,380	2,134	54
Oats	1951	Oklahoma	976	1,214	24
	1952	Oklahoma	227	1,308	476
	1954	Oklahoma	68	1,361	1,901
Barley	1951	Oklahoma	58	566	876
	1954	Oklahoma	379	1,373	262

APPENDIX A

TABLE 40

EFFECTS OF HERBICIDE USE ON CROP YIELDS[44]

VEGETABLE CROPS

Crop	Weeds Involved	Herbicide Used	Percent Increase in Yields in Experimental Plots
Carrots	Annual weeds	Amiben	157
Lettuce		Amiben	86
Onions	Annual weeds	CIPC	561
Spinach	Pigweed, purslane, henbit, crabgrass, barnyard grass	CIPC	12
Sweet Potatoes	Annual weeds	CDAA	27
Tomatoes	Pigweed, lambs-quarter, barnyard grass, foxtail, plantain	Solan	140

RANGELAND FORAGE CROPS

Crop	Weeds Involved	Herbicide	Yield (lb/acre) Without Herbicide	Yield (lb/acre) With Herbicide	Percent Increase
Forage, airdry	Shinnery oak	2,4,5-T	635	1,640	258
Forage, dry matter eaten by cattle	Blackjack oak and associated species	2,4,5-T	2,200	7,100	323
Forage, overdry	Low-grade hardwoods (Ozarks)	2,4,5-T	220	1,210	550
Grass, airdry	Sagebrush	2,4-D	526	2,075	394
Herbage production	Sagebrush	2,4-D	159	502	316
Grass, average production	Mesquite (Ariz.)	2,4,5-T	157	645	411
Forage grasses	Port-blackjack oak	2,4,5-T	223	1,290	578
Forage (animal unit months)	Sagebrush	2,4-D	702	1,372	195
Forage, airdry	Mixed hardwoods	2,4,5-T	164	1,796	1,095

(continued)

TABLE 40 (Continued)

EFFECTS OF HERBICIDE USE ON CROP YIELDS

PASTURE FORAGE CROPS

Crop	Weeds Involved	Herbicide	Yield (lb/acre) Without Herbicide	Yield (lb/acre) With Herbicide	Percent Increase
Forage herbage	Perennial and annual	2,4-D	1,100	2,800	254
Ladino clove	Curly dock	4-(2,4-DB)	2,800	6,000	214
Forage grass	Perennial and annual	2,4-D	2,000	4,000	200
Forage	Undesirable grasses	TCA	2,100	5,400	257
Alfalfa	Winter annuals	CIPC	3,000	4,600	153
Birdsfoot trefoil	Annuals	Dalapon	80	3,860	4,825
Alfalfa	Annuals	4-(2,4-DB)	460	1,750	380

TABLE 41

EFFECTS OF FUNGICIDE USE ON CROP YIELDS[44]

ORCHARD CROPS

Crop	Disease	Fungicide	Yield Untreated	Yield Treated	Quality Untreated	Quality Treated	Percent Yield Increase
Apple	Scab	Captan	2 ton/acre	8 ton/acre	1 ton/acre, good	7.0 ton/acre, good-fancy	300
Apple	Powdery mildew	Karaltane	3 ton/acre	6.5 ton/acre	2 ton/acre, good	6.0 ton/acre, good-fancy	117
Peach	Brown rot	Captan	3.5 ton/acre	6.8 ton/acre	1.7 ton/acre, good-fancy	6.5 ton/acre, good-fancy	126
Peach	Leaf curl	Ferbam	1 ton/acre	7 ton/acre	1 ton/acre, poor cull	6 ton/acre, good-fancy	600
Peach	Scab	Captan	0.5 ton/acre	7 ton/acre	0.5 ton/acre, poor cull	6.5 ton/acre, good-fancy	1,300
Cherry	Leaf spot	Dodine	1,700 lb/acre	2,600 lb/acre	1,300 lb/acre, good-fancy	2,600 lb/acre, good-fancy	53
Grape	Black rot	Ferbam	1,000 lb/acre	8,000 lb/acre			700
Pecan	Scab	Dodine	100 lb/acre	300 lb/acre	50 lb/acre, poor-good	150 lb/acre, fancy	200

(continued)

TABLE 41 (Continued)

EFFECTS OF FUNGICIDE USE ON CROP YIELDS

VEGETABLE CROPS

Crop	Disease	Fungicide	Yield		Quality		Percent Yield Increase
			Untreated	Treated	Untreated	Treated	
Tomatoes	Early blight and gray leafspot	Maneb	4.6 ton/acre	1.8 ton/acre			293
Cucumber	Scab	Maneb	51 bu/acre	148 bu/acre	31% U.S. 1	74% U.S. 1	190
Potatoes	Late blight	Maneb	360 cwt*/acre	418 cwt*/acre			16
Potatoes	Late blight and early blight	Maneb	258 cwt*/acre	402 cwt*/acre			56
Potatoes	Verticillium wilt	Vafam	74 cwt*/acre	330 cwt*/acre			347
Potatoes	Scab and scurf	PCNB	232 cwt*/acre	300 cwt*/acre	40 cwt*/acre, U.S. 1	224 cwt*/acre, U.S. 1	29
Sweet corn	Helminthosporium blight	Zineb	862 lb/acre	1,724 lb/acre	385 lb/acre, fancy	1,339 lb/acre, fancy	100
Lima beans	Downy mildew anthracnose	Maneb Zineb	2,180 lb/acre 82 bu/acre	3,855 lb/acre 355 bu/acre			77 333

(continued)

TABLE 41 (Continued)

EFFECTS OF FUNGICIDE USE ON CROP YIELDS

VEGETABLE CROPS

Crop	Disease	Fungicide	Yield		Quality		Percent Yield Increase
			Untreated	Treated	Untreated	Treated	
Onions	Downy mildew	Zineb	125 lb/300 bulbs	217 lb/300 bulbs			70
Corn	Seedling blight	Thiram	87.1 bu/acre	95.9 bu/acre			10
Cotton	Seedling diseases	Caresa	2,487 lb/acre	2,750 lb/acre			11

*cwt=hundred weight.

TABLE 42

INCREASING ANALYTICAL SENSITIVITY (MINIMUM DETECTABILITY) FOR PESTICIDES[35]

Year	Sensitivity
1930	10 ppm
1935	10 ppm
1940	10 ppm
1945	1 ppm
1950	0.1 ppm
1955	0.02 ppm
1960	1 ppb
1965	0.1 ppb

APPENDIX A

TABLE 43

MAJOR RESIDUE ANALYTICAL INSTRUMENTATION OR TECHNIQUES AND THEIR RESIDUE APPLICATIONS

Instrumentation or Technique	Application
Precision colorimetry	Measurement, rarely to support identification, sensitive
Gas chromatography, variety of detectors	Segregation, measurement, poor for identification, sensitive
Ultraviolet spectrophotometry	Measurement, occasionally to support identification, sensitive
Infrared spectrophotometry	Measurement, superior for comparative identification, sensitive
Radiotracer scanning and counting	Measurement, often superior for identification of element sought, very sensitive
Micropolarography	Measurement, often superior for identification, very sensitive
Mass spectrometry	Measurement, identification, not sensitive
Nuclear magnetic resonance spectrometry	Comparative, identification, not sensitive
Hydrogen ion measurement	Measurement, can be sensitive
Thin-layer chromatography	Segregation, poor for identification, rapid, versatile, can be sensitive
Paper chromatography	Segregation, poor for identification, sensitive
Column chromatography	Segregation, poor for identification, not sensitive

(continued)

APPENDIX A

TABLE 43 (Continued)

MAJOR RESIDUE ANALYTICAL INSTRUMENTATION OR TECHNIQUES AND THEIR RESIDUE APPLICATIONS

Instrumentation or Technique	Application
Countercurrent distribution	Segregation, identification by p-values, not sensitive
Fluorescence spectrometry	Measurement, identification, very sensitive
Phosphorescence spectrometry	Measurement, identification, very sensitive
Paper and zone electrophoresis	Segregation, characterization, sensitive
Titrimetry	Measurement, sensitive
X-ray spectrometry	Measurement, identification sensitive

APPENDIX A

TABLE 44

CHRONOLOGY OF GAS CHROMATOGRAPHIC DETECTION SYSTEMS USED IN PESTICIDE RESIDUE EVALUATIONS[106]

Detection System	Responding Element(s)	Year Announced	Approximate Minimum Detectability	
			Ideal[a]	Practical[b]
Flame ionization	C	1958	ng	μg
Electron-capture	Electron-transferring	1960	pg	ng
Microcoulometric	Cl	1960	ng	ng
	S	1961	ng	μg
	N	1966	ng	μg
Beilstein flame	Cl	1961	ng	μg
Thermionic	Cl,P	1964	pg	ng
Electrolytic-conductivity	Cl,S	1964	μg	μg
	Cl,S,N	1965	ng	ng
Spectrometric:				
Microwave emission	Cl,S,P[c]	1965	ng[d]	ng[d]
Flame emission	S,P	1966	pg	ng
Mass	Structural units	1966	μg	μg[e]
Infrared	Bonding	1960	μg	μg
Ultraviolet	Pi electrons	Being developed	μg-mg	μg-mg

[a] With purified compounds and purified solvents.

[b] In the presence of substrate extractives, after some "cleanup."

[c] Demonstrable in various oxidation states.

[d] Organophosphates.

[e] About 0.1 μg in some residue studies.

APPENDIX B

APPENDIX B

PESTICIDE GLOSSARY[31,68,69,92]

Common Name	Chemical Name	Use
Abate	0,0-dimethyl phosphorothioate 0,0-diester with 4,4'-thiodiphenol	insecticide
acrylonitrile	acrylonitrile	fumigant
aldrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endoexo-5,8-dimethanonaphthalene	insecticide
aluminum phosphide	aluminum phosphide	insect fumigant
amiben	amino-2,5-dichlorobenzoic acid	herbicide
ammonium sulfamate	ammonium amidosulfate	herbicide
ANTU	alpha-naphthyl thiourea	rodenticide
atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-triazine	herbicide
azinphosmethyl	0,0-dimethyl S [4-oxo-1,2,3-benzotriazin-3(4H)ylmethyl] phosphorodithioate	fungicide
Azodrin	3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
baygon	o-isopropoxyphenyl methyl carbamate	insecticide
benzene hexachloride (BHC)	1,2,3,4,5,6-hexachlorocyclohexane (mixture of isomers)	insecticide
Bidrin	3-hydroxy-N,N-dimethyl-cis-crotonamide dimethyl phosphate	insecticide
binapacryl	2-sec-butyl-4,6-dinitrophenyl 3-methyl-2-butenoate	insecticide
borax	sodium biborate	fungicide, herbicide
Brassicol	pentachlorophenol	fungicide
bromoxynil	4-hydroxy-3,5-dibromobenzonitrile	herbicide
cacodylic acid	dimethylarsinic acid	herbicide, defoliant
calcium arsenite	mono-calcium arsenite	insecticide
calcium cyanamide	calcium carbimide	herbicide
carbaryl	1-naphthyl N-methylcarbamate	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
carbon disulfide	carbon disulfide	insecticide, fumigant
carbon tetrachloride	carbon tetrachloride	insecticide
carbophenothion	S-[[(p-chlorophenyl)thio]methyl] 0,0-diethyl phosphorodithioate	insecticide
CDAA	2-chloro-N,N-diallylacetamide	herbicide
chloranil	tetrachloro-p-benzoquinone	fungicide
chlordane	1,2,3,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	insecticide
chlorobenzilate	ethyl 4,4'-dichlorobenzilate	insecticide
chloroform	chloroform	insect fumigant and ingredient in screw-worm smears
chloropicrin	trichloronitromethane	fumigant, insecticide, fumicide, rodent repellent
chloroxuron	N'-(4-chlorophenoxy) phenyl N,N-dimethylurea	herbicide

(continued)

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
Ciodrin	alpha-methylbenzyl 3-hydroxycrotonate dimethyl phosphate	insecticide
coal tar	by-product of coal distillation	insecticide, fungicide
Compound 5353	m(1-methylbutyl) phenyl methylcarbamate	
copper naphthenate	cupric cyclopentanecarboxylate	fungicide, especially in wood and fabric preservation
copper 8-quinolinolate	copper 8-hydroxyquinolinate	fungicide
copper sulfate (blue copperas)	cupric sulfate	fungicide
coumaphos	0,0-diethyl 0-(3-chloro-4-methyl-2-oxo-2H-1-benzopyran-7-yl) phosphorothioate	insecticide
Crag 169	copper zinc chromate complexes	fungicide
creosote	creosote, a mixture of phenols obtained from wood tar	wood preservative

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
cryolite	sodium hexafluoroaluminate	insecticide
cube (root)	rotenone	insecticide
2,4-D	2,4-dichlorophenoxyacetic acid	herbicide
dalapon	2,2-dichloropropionic acid, sodium salt	herbicide
DDA	bis (chlorophenyl) acetic acid, (degradation product of DDT)	
DDE	dichlorodiphenyl dichlorethylene (degradation product of DDT)	
DDT	1,1,1-trichloro-2,2-bis p-chlorophenyl) ethane	insecticide
demeton	mixture of 0,0-diethyl S(and 0)-[2-(ethylthio)ethyl] phosphorothioates	insecticide
Dexon	p-dimethylaminobenzenediazo sodium sulfonate	
Diazinon	0,0-diethyl 0-(2-isopropyl 4-methyl-6-pyrimidyl) phosphorothioate	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
dichlone	2,3-dichloro-1,4-naphthoquinone	fungicide, herbicide
dichloropropene	1,3-dichloropropylene	soil fumigant, herbicide, insecticide, fungicide, nematocide
dichlorvos (DDVP)	0,0-dimethyl-0-2,2-dichlorovinyl phosphate	insecticide
dicofol	4,4'-dichloro-alpha-(trichloromethyl)-benzhydrol	insecticide
dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethano-naphthalene	insecticide
dimethoate	0,0-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate	systemic acaricide, insecticide
dinitrocresol	4,6-dinitro-o-cresol	insecticide, herbicide
diquat	1,1'-ethylene-2,2'-dipyridinium dibromide	herbicide, desiccant

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
disulfoton	0,0-diethyl S-[2-(ethylthio) ethyl] phosphorodithioate	insecticide
diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	herbicide
DN-111	dicyclohexylamine salt of 2-cyclohexyl-4,6-dinitrophenol	insecticide
DNBP (dinitrobutylphenol)	2,4-dinitro-6-sec-butylphenol	herbicide, insecticide
2,4-DP (dichlorprop)	2-(2,4-dichlorophenoxy) propionic acid	herbicide
endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,-9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide	insecticide
endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene	insecticide
EPN	0-ethyl-0-p-nitrophenyl phenylphosphonothioate	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
ethion	0,0,0',0'-tetraethyl S,S'-methylenebisphosphorodithioate	insecticide
ethylene dibromide	1,2-dibromoethane	fumigant, nematocide
ethyl formate	ethyl formate	fumigant
ethylene dichloride	1,2-dichloroethane	insecticide
ethylene oxide	ethylene oxide	herbicide
fenthion	0,0-dimethyl [0- 4-(methylthio)-m-tolyl] phosphorothioate	acaricide, insecticide, bird control
ferbam	ferric dimethyldithiocarbamate	fungicide
Fumazone	1,2-dibromo-3-chloropropane	soil fumigant, nematocide
heptachlor	1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-endo-methanoindene	insecticide
hydrogen cyanide	hydrocyanic acid	insect fumigant

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
Kepone	decachloroöctahydro-1,3,4-metheno-2H-cyclobuta [cd] pentalen-2-one	insecticide
lead arsenate	diplumbic hydrogen arsenate	insecticide, fungicide
lime sulfur	30 percent calcium polysulfide and various small amount of calcium thiosulfate plus water and free sulfur	acaricide, fungicide, insecticide
lindane	gamma isomer of 1,2,3,4,5,6-hexachlorocyclohexane of 99+%	insecticide
malathion	S-[1,2-bis(ethoxycarbonyl)ethyl] 0,0-dimethyl phosphorodithioate	insecticide
MCPA	4-chloro-2-methyl-phenoxyacetic acid	herbicide
MCPB	4-chloro-2-methylphenoxy butyric acid	herbicide
MCPP	2-(4, chloro-2-methyl-phenoxy) propionic acid	herbicide
metaldehyde	metaldehyde	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
methoxychlor	1,1,1-trichloro-2,2-bis (p-methoxyphenol) ethane	insecticide
methyl bromide	bromomethane	fumigant
methyl chloride	chloromethane	aerosol propellent
methyl formate	methyl formate	insect fumigant
methyl parathion	0,0-dimethyl 0-p-nitrophenyl phosphorothioate	insecticide
Methyl Trithion	S-[[(p-chlorophenyl)thio]methyl] 0,0-dimethyl phosphorodithioate	insecticide
mevinphos	methyl 3-hydroxy-alpha-crotonate dimethyl phosphate	insecticide
mirex	dodecachlorooctahydro-1,3,4-metheno-2H-cyclobuta [Cd] pentalene	insecticide
Morestan	6-methyl-2-oxo-1,3-dithio (4,5-b) quinoxaline	acaricide, fungicide
nabam	disodium ethylene bisdithiocarbamate	fungicide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
naled	1,2-dibromo-2,3-dichloroethyl dimethyl phosphate	insecticide
naphthalene	naphthalene	insecticide
neburon	3-(3,4-dichlorophenyl)-1-methyl-1-n-butylurea	herbicide
Nemacide	0-2,4-dichlorophenyl 0,0-diethyl phosphorothioate	insecticide
nicotine	L-3-(1-methyl-2-pyrolidyl) pyridine	insecticide
nicotine sulfate	nicotine sulfate	insecticide
ovex	p-chlorophenyl p-chlorobenzene-sulfonate	insecticide
paradichlorobenzene	p-dichlorobenzene	insect fumigant
Paraquat	1,1'-dimethyl-4,4'-dipyridylium cation	herbicide
parathion	0,0-diethyl-0-p-nitrophenyl phosphorothioate	acaricide, insecticide
paris green	copper acetoarsenite	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
Patoran	4-(4-bromophenyl)-1-methyl-1'-methoxyurea	herbicide
pentachlorophenol	sodium pentachlorophenate	defoliant, herbicide, insecticide, fumgicide, wood preservative
Perthane	1,1-dichloro-2,2-bis(p-ethylphenyl) ethane	insecticide
petroleum oils		acaricide, insecticide, herbicide
phorate	0,0-diethyl S-[(ethylthio)methyl] phosphorodithioate	insecticide
phosphamidon	2-chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate	insecticide
pindone	2-pinaloyl-1,3-indandione	rodenticide, insecticide
piperonyl butoxide	(butyl carbitol) (6-propyl piperone) ether	insecticide synergist
PMA	phenylmercuric acetate	fungicide, herbicide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
propanil	3',4'-dichloropropionanilide	herbicide
propylene chloride	dichloropropane	soil fumigant, herbicide, insecticide, fungicide, nematocide
propylene oxide	propylene oxide	insecticide synergist
pyrazon	5-amino-4-chloro-2-phenyl-3 (2H) pyridazinone	herbicide
pyrethrins	the active insecticidal constituents of pyrethrum	insecticide
pyrethrum	dalmatian insect flowers	insecticide
red squill	inner bulb scales of *Urginea maritima*	rodenticide
ronnel	0,0-dimethyl 0-2,4,5-trichlorophenyl phosphorothioate	insecticide
rotenone	the primary active compound of derris and cube roots	insecticide
Ruelene	4-tert-butyl-2-chlorophenyl methyl methylphosphoramidate	insecticide

(continued)

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
ryania	powdered stemwood of _Ryania speciosa_	insecticide
sabadilla	ground seeds of sabadilla containing veratrine, a complex mixture of alkaloids	insecticide
sodium arsenite	sodium meta-arsenite	herbicide, insect poison bait ingredient
sodium chlorate	sodium chlorate	herbicide (desiccant)
sodium N-methyldithiocarbamate	sodium N-methyldithiocarbamate	fungicide, herbicide, nematocide
Strobane	terpene polychlorinates	insecticide
strychnine	_Nux vomica_ alkaloid	rodenticides; used in poison baits for birds, moles, and other rodents
sulfur (brimstone)	sulfur	acaricide, fungicide
sulfuryl fluoride	sulfuryl fluoride	insecticide, fumigant

(continued)

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
Sumithion	0,0-dimethyl 0-(4-nitro-m-tolyl) phosphorothioate	Insecticide, space fumigant
2,4,5-T	2,4,5-trichorophenoxyacetic acid	herbicide
tartar emetic	antimony potassium tartrate	herbicide
2,3,6-TBA	2,3,6-trichlorobenzoic acid	herbicide
TDE (DDD)	2,2-bis (p-chlorophenyl)-1,1-dichloroethane	insecticide
Telone	mixed dichloropropenes	insecticide
TEPP	tetraethyl pyrophosphate	insecticide
tetradifon	p-chlorophenyl 2,4,5-trichlorophenyl sulfone	insecticide
thiram	tetramethyl thiuram disulfide	fungicide, animal repellent
toxaphene	chlorinated camphene	insecticide

(continued)

APPENDIX B

PESTICIDE GLOSSARY

Common Name	Chemical Name	Use
trichlorfon	0,0-dimethyl (1-hydroxy-2,2,2-trichloroethyl) phosphonate	systemic insecticide
2,4,5-trichlorophenol	sodium 2,4,5-trichlorophenate	fungicide
warfarin	3-(1'-phenyl-2'-acetylethyl)-4-hydroxy-coumarin	rodenticide
white arsenic	arsenic trioxide	animal dip, herbicide, ingredient in insect baits
Zectran	4-dimethylamino-3,5-xylyl N-methylcarbamate	pesticide for control of snails and slugs
zinc white	zinc oxide	ingredient in animal remedies
zineb	zinc ethylene bisdithiocarbamate	fungicide
Zinophos	0,0-diethyl 0-2-pyrazinyl phosphorothioate	insecticide, fungicide, nematocide